Materials in Design Engineering

FORMERLY
MATERIALS
& METHODS

SELECTION & USE OF METALS, NONMETALLICS, FORMS, FINISHES

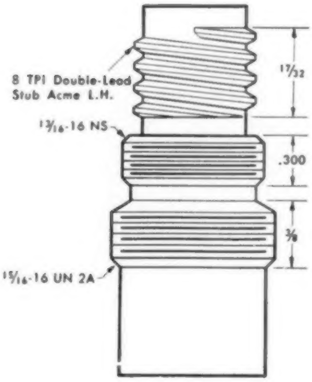
Physical Properties and Tests

Manual No. 159

Also:
Complex Tungsten Parts
New Epoxy Molding Materials
Complete Contents—page 1

UNE, 1959

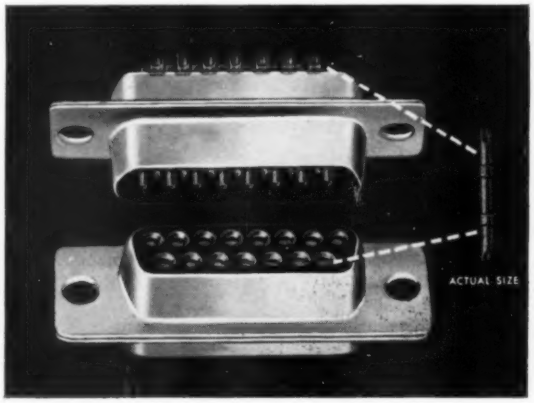
COST CUTTING on tough jobs–like rolling a double-lead Stub Acme thread–may be easier than you think. Olson Mfg. Co. needed only a minor adjustment in a standard Anaconda rod

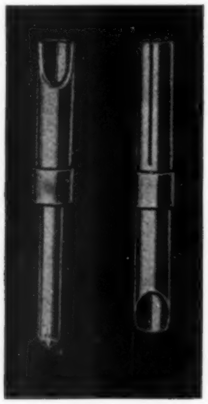


Rolling three threads *(drawing, right)* in two positions on a 6-spindle automatic meant cost savings for Olson Mfg. Co., Worcester, Mass. The Acme thread, however, posed problems. American Brass specialists suggested minor modification of standard Anaconda Free-Cutting Brass Rod to provide the extra ductility needed. The idea worked and the resulting valve spindle is shown above, about 1½ times actual size.

—or maybe you need a different alloy rod. The tiny connectors, right, have to be machined from .078" rod, requiring many precision form-cutting, drilling, slotting operations. So machinability is a vital property of the rod used—but so are adequate electrical conductivity, high strength, and fatigue resistance.

Cannon Electric, Los Angeles, makers of these electrical plug assemblies, had to find a rod with a delicately balanced combination of mechanical properties to provide the unfailing and continuous performance required. They found it in Anaconda Free-Cutting Phosphor Bronze-610 Rod, developed by American Brass metallurgists to combine the strength, resilience, fatigue resistance of phosphor bronze, and machinability approaching that of free-cutting brass.





MEETING the joint requirements of designers, manufacturing men, and buyers—to achieve high quality and performance while simplifying fabrication and cutting over-all costs—is an important function of American Brass technical specialists. For imaginative and practical help of this kind, see your American Brass Company representative or write: The American Brass Company, Waterbury 20, Conn. In Canada: Anaconda American Brass Ltd., New Toronto, Ont. 5939

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Materials

in Design Engineering. *formerly Materials & Methods*

Selection & use of metals, nonmetallics, forms, finishes

JUNE 1959
VOL. 49, NO. 6

FEATURES

DEPARTMENTS

PUBLISHED BY
REINHOLD PUBLISHING CORP.
430 PARK AVE., NEW YORK 22, N. Y.

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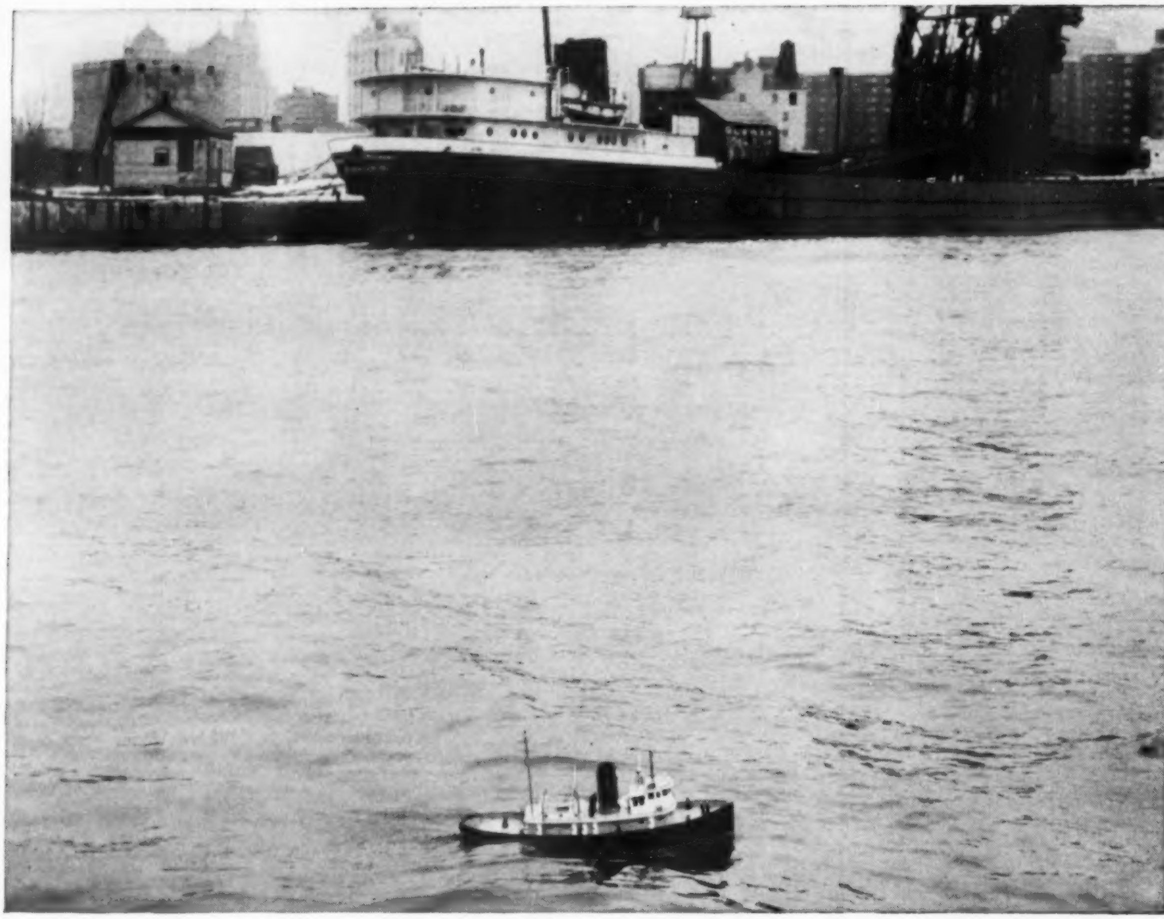

World's smallest Monel shaft delivers model performance

When radio-controlled *Polaris* sets out for a run on the Buffalo River, she's every inch a working tugboat. Although she's only 34 inches long, the river is as rough on her as it is on life-size boats.

Take her shaft, for example. Her tiny engine delivers brutal shocks to it. Then, when choppy water lifts her stern into the air, the propeller revs up wildly. And big boat or small, when a propeller hits a piece of driftwood—it's trouble.

Like so many of her bigger sisters, *Polaris* was originally equipped with an ordinary metal shaft. And also like so many of her bigger sisters, she used to bend up her shafts. They just couldn't take it.

That's when Polaris' owner equipped her with a Monel* nickel-copper alloy shaft. It's probably the world's smallest . . . just over 4¼ inches long, only ⅛ inch in diameter. It's extra-strong—withstands engine torque. Extra-stiff—shrugs off whip. Extra-hard—stays smoother longer. And, highly corrosion-resisting.

This application of Monel alloy is small, in terms of quantity. But its significance is as big as you make it. That's why we ask . . .

Do you have a metal problem? One where corrosion, abrasion, high or low temperatures, stress or fatigue is causing you trouble? Let's talk it over. There's a very good chance one of the Inco Nickel Alloys may be able to give you the model performance *you've* been looking for. Why not set up a date to discuss it.

Owner-builder H. H. Larkin, Jr. indicates Monel shaft on *Polaris*. When the makers of Veco Products Corp. Kits heard of Mr. Larkin's experience, they switched to Monel alloy for all their shafts.

*Registered trademark of The International Nickel Company, Inc.

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What's new IN MATERIALS

...AT A GLANCE

A new low temperature polyethylene copolymer is reported to have outstanding low temperature toughness. Garbage cans molded of the material and tested at 10 F have withstood crushing by a 16-ton truck without damage. The polyethylene can easily withstand 6-ft drop tests at —10 F. The injection molding grade now available has a density of 0.935 gm/cu cm and a melt index of 8 gm/10 min. In comparison with existing polyethylenes of similar plastic flow, the material is also said to have five times greater flex life and superior stress cracking resistance. Though its composition has not been revealed, the material is said to be radically different from previously announced ethylene copolymers.
Source: Union Carbide Plastics Co., Div. of Union Carbide Corp., 30 E. 42nd St., New York 17.

Large nickel parts with overall dimensional tolerances of ±0.0005 in. have been produced by a new fabricating technique called "electrolytic casting." The process is similar to electroforming in that it works by electrodepositing nickel or other metals on a mandrel. (More details next month.)
Source: C. L. Duncan, 2675 Candler Rd., Chamblee, Ga.

Relatively non-brittle, heat resistant cermets have come out of the development of a new method for combining ceramics and metals. The method works as follows: 1) a metal layer and a ceramic layer are flame sprayed on a rotating disk; 2) after cooling the ceramic-metal layer is crushed into small grains with each grain retaining the laminated ceramic-metal structure; 3) the grains are then hot pressed in a graphite mold at 2200 F. The resulting cermet is said to be considerably less brittle than ceramics because the metal layer provides "slippage" for the ceramic layer.
Source: Prof. F. R. Shanley, University of California, Los Angeles.

Color controlled polystyrene molding compounds are now commercially available. Color is controlled by a series of electronic instruments and computers that take into account the three color variables of hue, purity and value. Heretofore, color of plastics compounds was controlled by visual methods. Data supplied with each shipment verifies that the color of the compound matches that of past shipments.
Source: Monsanto Chemical Co., Plastics Div., Springfield, Mass.

Two magnesium casting alloys for high temperatures have been developed. One is a rare-earth-silver-zirconium alloy called MSR that is said to have the highest yield strength of any magnesium casting alloy yet developed (25,000 psi). Other characteristics of MSR are good tensile properties at temperatures up to 500 F and good short-time creep strength at 400 F. The other new alloy is a rare-earth-zirconium alloy called EK31XA that is said to have excellent tensile strength

properties at temperatures up to 600 F. Both alloys have good resistance to stress corrosion cracking.
Source: Magnesium Elektron Inc., 630 5th Ave., New York 20 (MSR) and Dow Chemical Co., Midland, Mich. (EK31XA).

A new corrosion inhibitor has successfully been used to dry out and return a water-soaked electric motor to operating condition in less than 15 min. The inhibitor, composition of which has not been revealed, can also be used to remove rust and contaminants from metals, plastics and painted surfaces.
Source: Corrosion Reaction Consultants, Inc., Philadelphia.

Two high temperature columbium-base alloys, now commercially available, have been developed for use in rockets and missiles. One is a columbium-zirconium alloy with a melting point of 4350 F and a density of 0.311 lb per cu in.; the other is a columbium-tantalum-zirconium alloy with a melting point of 4550 F and a density of 0.371.
Source: Fansteel Metallurgical Corp., North Chicago, Ill.

Electronic equipment 1000 times smaller and lighter than anything now in existence may come out of the development of a new method for growing germanium crystals. The method is said to grow thin, flat strips of germanium in the exact form in which they are used in electronic devices. By using the crystals in a telemetry subsystem the number of parts were cut from 14 to 1 and soldered connections from 15 to 2.
Source: Westinghouse Electric Corp., Box 2278, Pittsburgh 30.

Flexible fluoride films show promise as high temperature electrical insulations on copper, aluminum and other metal wires. The insulating films are formed by exposing metal to oxidizing carriers of fluorine such as hydrogen fluoride or elemental fluorine at temperatures from 500 to 1100 F. The resulting fluoride films have high electrical insulating values at temperatures up to 900 F and have good resistance to oxidation at temperatures above 1100 F. They do not hydrate or dissolve on exposure to high humidity and do not break down on exposure to 450 v at 900 F. (More details next month.)
Source: Bell Telephone Laboratories, 463 West St., New York 14.

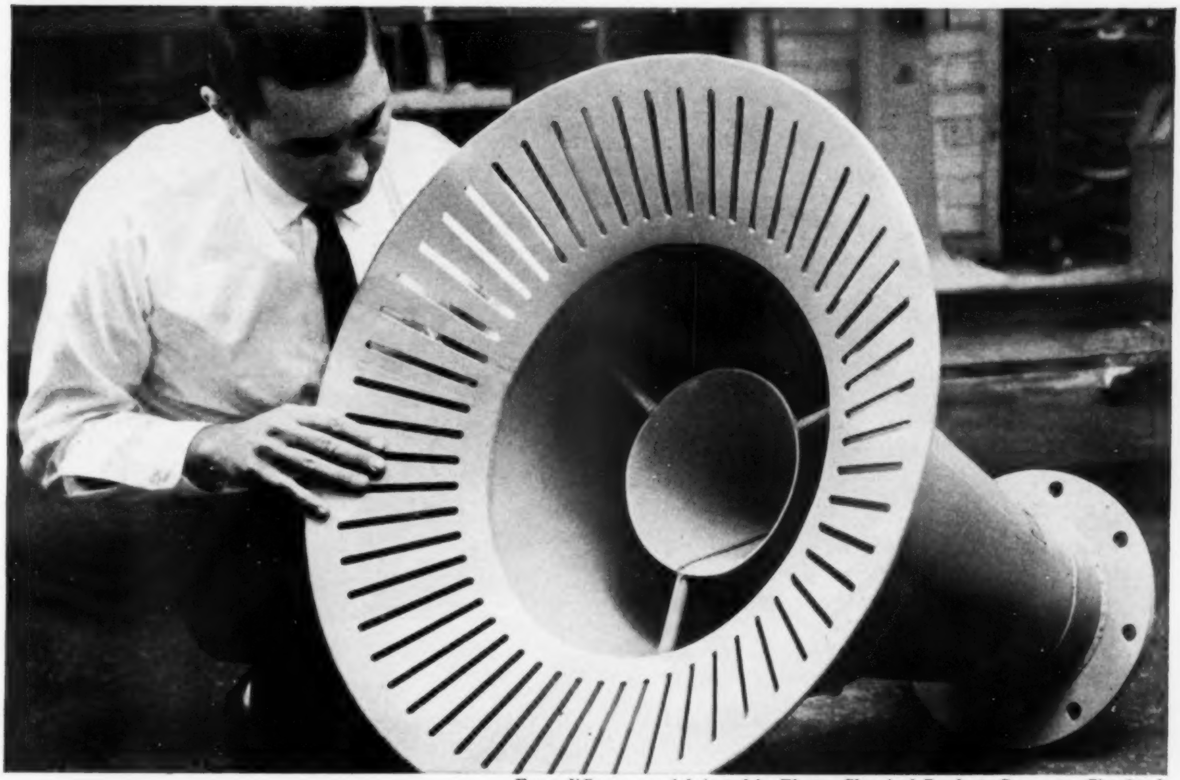
A nickel-base alloy for use with molten fluoride salts and other corrosive chemicals is now being produced on a developmental basis. An outstanding characteristic of the alloy is its good resistance to embrittlement after continuous exposure to temperatures up to 1600 F. The alloy also has good oxidation resistance at temperatures up to 1800 F. (More details in a forthcoming issue.)
Source: Haynes Stellite Co., Div. of Union Carbide Corp., 420 Lexington Ave., New York 17.

Silicon carbide foam is said to have excellent thermal insulating properties at temperatures up to 4000 F. The material, now in pilot plant production, can be machined easily with standard steel cutting tools, and can be fabricated into complex shapes at close tolerances. The self-bonded insulation is highly resistant to most corrosive chemicals and some molten metals.
Source: Carborundum Co., Research & Development Div., Niagara Falls, N. Y.

Turn to page 115 for more "What's New in Materials"

News about

B.F.Goodrich Chemical *raw materials*



Fume diffusers are fabricated by Electro-Chemical Products Company, Cleveland, Ohio, of sheets of rigid Geon made by Seiberling Rubber Company, Newcomerstown, Ohio. B.F.Goodrich Chemical Company supplies the Geon polyvinyl material only.

FUME DIFFUSERS TOOK A LICKING FROM CORROSION

. . . till the cones were made from GEON

THESE cones of Geon rigid vinyl show how you can solve corrosion problems. They are used to diffuse hydrofluoric and chromic acid fumes in a chemical plant, where cones of metal and other plastic were tried first.

Geon rigid vinyl solves corrosion problems—because it withstands acids, oils and many hydrocarbon chemicals. Geon also provides for accuracy in fabrication. For example, the sheet of rigid Geon from which these cones were made was machined to extremely close tolerance—.003 inches for the slots—to give the cones the exact design for most efficient fume dispersion.

Products of versatile Geon polyvinyl materials can be made in rigid form, rotationally cast, slush molded, calendered, extruded or blown into foam form. Applications range from solving all types of corrosion problems from piping to ductwork, to coatings for paper, metal and other materials.

For information on Geon polyvinyl raw materials, write Dept. AR-2 B.F.Goodrich Chemical Company, 3135 Euclid Avenue, Cleveland 15, Ohio. Cable address: Goodchemco. In Canada: Kitchener, Ontario.

Geon *Polyvinyl Materials*

B.F.Goodrich Chemical Company
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MATERIALS AT WORK

...AT A GLANCE

Aluminum rifle is easy to handle

Light weight, corrosion resistance and ability to be anodized in a variety of colors are the reasons given for the use of aluminum in a new slide action, .22 caliber rifle. Aluminum is used for the receiver, trigger guard, butt plate, and jacket for the steel barrel liner. The rifle, said to be suited to both hunting and target shooting, weighs only 4 lb.

Source: Aluminum Co. of America; rifle manufactured by Remington Arms Co., Inc.

Nylon door hinge won't squeak

A one-piece nylon hinge that is said not to squeak, stick, shatter, embrittle, corrode or wear, is now available. The hinge can be molded to meet any requirements of color, shape or finish; it can be used for doors, luggage and furniture; and it is especially suitable for shipboard applications because it resists salt water. Major advantages: self lubricating properties, high impact strength and low coefficient of friction.

Source: American Plastics Corp., Div. of Heyden Newport Chemical Corp.

Titanium tubing replaces glass in heat exchanger

A saving of over $1500 in yearly maintenance cost has resulted from the switch from glass to titanium tubing in a cold water heat exchanger used to cool sodium hypochlorite. Previously, 2400 ft of 2-in. dia glass tubing were used. However, excessive breakage, shutdowns, labor costs and contamination dictated a change in materials. Welded titanium tubing, fabricated by a special technique, solved the problem. Titanium tubing used has a 5/8-in. o.d. and a 0.020 in. wall. Cost is about the same.

Source: Alloy Tube Div., Carpenter Steel Co.; exchanger used by Kuehne Chemical Co.

PVC piping best for plating operation

The use of rigid polyvinyl chloride piping is said to have reduced costs and increased efficiency of a plating operation in the production of mechanical fasteners. The piping is used to carry de-ionized water and hydrochloric, nitric, acetic and phosphoric acids under 40 psi and 60-90 F. Polyvinyl chloride was specified (in preference to commonly used aluminum, rubber-lined metal and cast ferrous alloy piping) because it offers the required combination of characteristics: 1) corrosion resistance, 2) low cost, 3) light weight, and 4) elimination of galvanic or electrolytic action. In addition, it will not contaminate or discolor the acid solutions.

Source: Tube Turns Plastics, Inc.; used by Fastener Div., National Lock Co.

Stainless trim replaces brass on boats

The switch from chromium-plated brass tubing to welded 302 stainless steel tubing has resulted in a 25% cost saving in the production of hand rails and trim for small boats. Reasons given for the selection of stainless: it is easier to bend, requires less polishing, offers excellent resistance to marine corrosion, is less expensive, and will not flake or peel. Tubing used has a 1-in. o.d. and a 0.049-in. wall.

Source: Formed Steel Tube Institute; tubing used by Trojan Boat Co.

Acrylic bar illuminates TV dial without bulb

Injection molded acrylic bars are replacing light bulbs in new television sets. The curved bars, which are snapped into place behind a dial, pick up light rays from a bulb used to illuminate another dial. The

(continued on p 9)

Briefs

Organic dyes are expected to replace hyperpure silicon in solar electric batteries. Preliminary investigations indicate that higher efficiencies can be obtained.

Drowning mice will have no straws to grasp in a new 12-lb steel trap that can catch up to 100 mice with one setting. The mouse, enticed by the smell of food in an inaccessible chamber, passes through a series of ramps and dumping mechanisms until it is finally dropped (by its own weight) into a water chamber.

Nylon hyperdermic syringes, a new British development, are said to be strong, long wearing and unbreakable. Another major advantage: plunger and barrel are replaceable when worn.

MATERIALS AT WORK

light rays are transmitted through a series of curves until they emerge from the end of the bar and backlight the dial. Acrylic was chosen because it 1) is easy to mold, 2) has excellent light transmitting properties, 3) is almost crystal clear, 4) has a smooth surface, and 5) will not conduct electricity.
Source: Chicago Molded Products orp.; used in Motorola UHF TV.

Ductile iron spools most efficient

The switch to cast ductile iron has resulted in a 20-30% cost saving in the production of spools used for stranding steel wire. Two spool sizes are involved: the 5-in. spools, previously made of machined carbon steel, had crevices where the flanges joined the spool barrel, and frequently a wire would snag and cause production delays and wire waste. The 9-in. spools, previously made of cast malleable iron, were too weak.
Source: T. B. Wood's Sons Co.; spools used by John A. Roebling's Sons Co.

Glass-silicone breaker strips resist 500 F

A glass-silicone laminate has solved a difficult heat-insulating problem in the design of breaker strips used around door openings of environmental test chambers. The chamber generates temperatures ranging from –125 to 500 F, and humidities ranging from 20 to 95%. The glass silicone laminate, which replaced a previously used paper-base phenolic laminate, was selected because it has nearly twice the heat resistance and about three times more resistance to water absorption.
Source: Taylor Fibre Co.; chambers made by Webber Engineering Corp.

Iron powder part reduces costs

Higher strength, closer tolerances and lower costs are the advantages claimed for the use of a single iron powder metal part instead of the three steel stampings, one screw machine part and two rivets previously used in the coin assembly of a vending machine. In addition to reducing the number of components, the metal powder part also eliminates these secondary operations: milling, drilling, tapping, riveting and assembling.
Source: Amplex Div., Chrysler Corp.; part used by Lehigh, Inc.

Flat fluorescent lamps on the way

Thin, rectangular glass plate may some day replace conventional tubular fluorescent lamps. The fluorescent light is produced when an arc or electric discharge traverses a labyrinth sealed within the glass. A typical experimental model measures 24 × 8 × 1 in. thick.
Source: Westinghouse Electric Corp.

(more Materials at Work on next page)

MATERIALS AT WORK

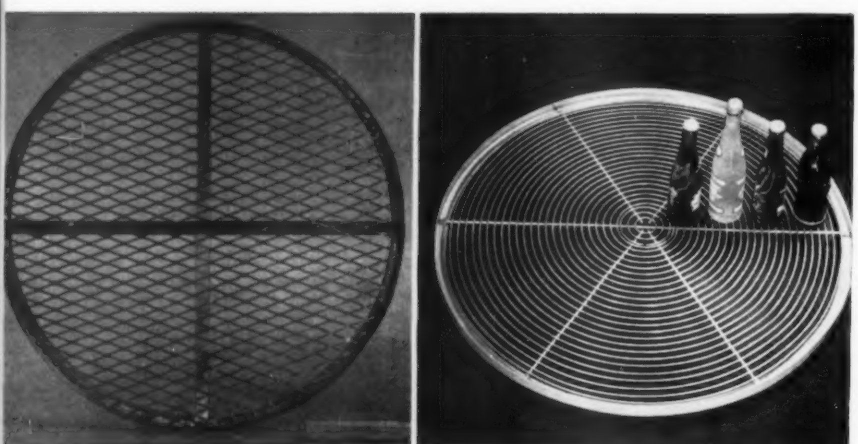
Edited by
Walter Lubars

Six case histories show how

Wire assemblies cut costs, improve design

Wire and wire strip assemblies are becoming increasingly popular with engineers and designers because of their strength, adaptability, resiliency, light weight, durability, low cost and attractive appearance. The accompanying case histories, supplied by E. H. Titchener & Co., illustrate many of these advantages.

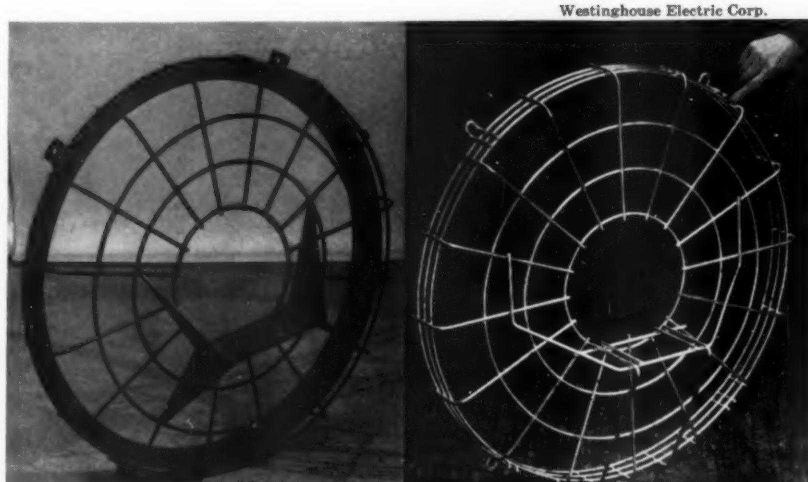
Currently available wire diameters range from 0.035 to 0.375 in. Ferrous metals used include: basic steel (most widely used), galvanized steel, Bethanized steel, coppered or tinned steel, spring wire, stainless steel, Copperweld, Nickelply and Copperply. The most widely used nonferrous metals are: copper, brass, bronze, nickel silver, aluminum and monel. Available finishes include: electroplating (especially nickel, chromium, brass, cadmium and zinc), enameling and lacquering.



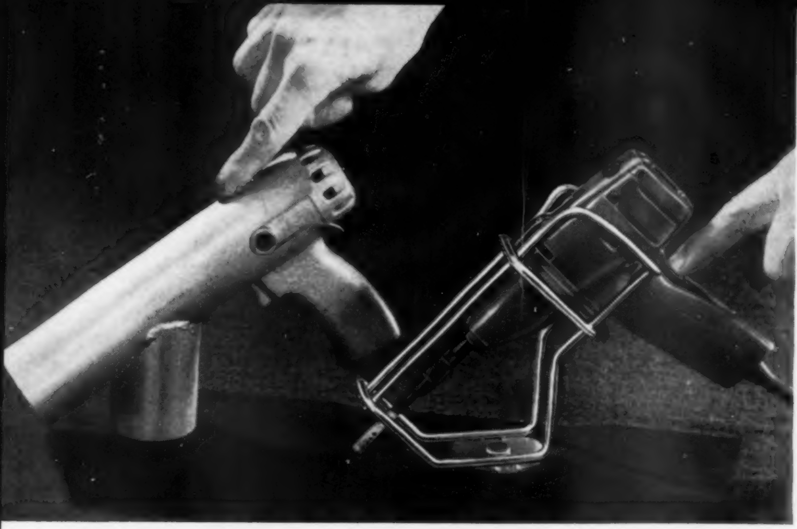
Uniflow Mfg. Co.

Shelf used to support bottles in a beverage cooler-dispenser. *Original material:* expanded metal welded to angle and band steel. *New material:* 0.16-in. steel wire spiral welded to 6 radial supports and a Z-frame hoop. *Reasons for change:* excessive costs; material not easily available; unit had to be reinforced to support required 200-lb load. *Advantages of wire assembly:* 15% weight reduction; greater strength (reinforcement unnecessary). *Cost:* approximately $1.20 less per unit.

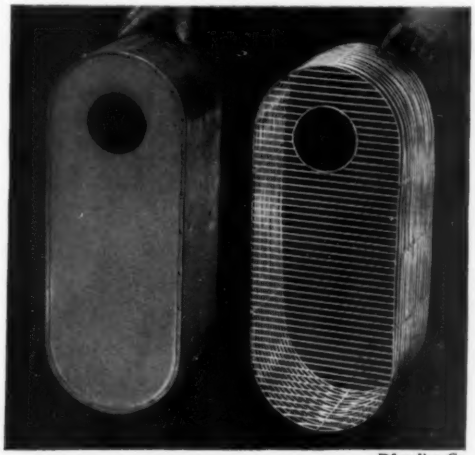
Westinghouse Electric Corp.



Motor mount and guard for a transformer cooling fan. *Original material:* strip steel, a wire frame, and a heavy cast rim. *New material:* 1/4 and 5/16-in. welded steel wire. *Reasons for change:* excessive weight; high cost; inability to obtain close tolerances. *Advantages of wire assembly:* weight reduction of about 44% (from 24 to 13½ lb); improved appearance; closer tolerances. *Cost:* reduced by about 65% (from $11.00 to $3.85 per unit).



Holster for electric tool. *Original material:* arc welded steel tubing. *New material:* steel wire, small round stampings. *Reasons for change:* excessive cost; inflexibility. *Advantages of wire assembly:* design fits several types of tools; 10% weight reduction. *Cost:* reduced by 66%.

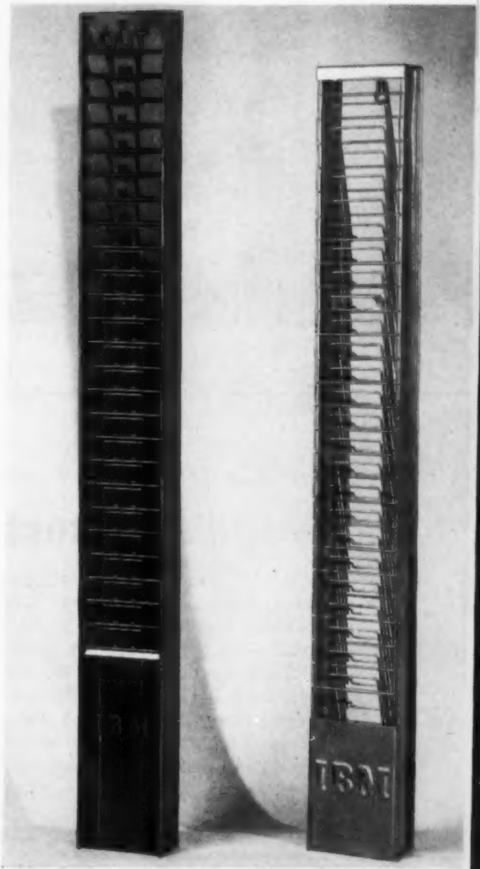


Pfaudler Co.

Belt guard used on process machinery. *Original material:* spot welded sheet steel. *New material:* 0.12-in. bright steel wire. *Reasons for change:* unattractive appearance; poor air circulation; poor access for inspection and maintenance. *Advantages of wire assembly:* better air circulation; improved appearance; ease of inspection; 15% weight reduction. *Cost:* reduced by 20%.

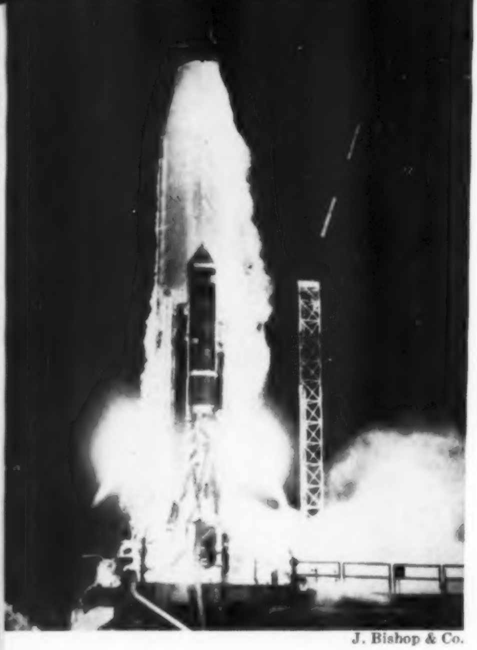
General Electric Co.

Bracket used to hold two-way radio plugs on chassis. *Original material:* six parts—spring steel mounting clip, stamped mounting plate, screw-machined hex-threaded spacer, a screw, and two lock washers. *New material:* two spotwelded pieces of 3/8 x 1/16-in. cold rolled steel strip. *Reasons for change:* complicated assembly; excessive cost. *Advantages of wire assembly:* reduced manufacturing time; 50% weight saving; simple assembly. *Cost:* reduced by 75%.



International Business Machines Corp.

Time card rack. *Original material:* resistance welded sheet steel. *New material:* a small amount of sheet steel; narrow strip steel; and 0.11-in. resistance welded round steel wire. *Reasons for change:* elimination of sheet steel. *Advantages of wire assembly:* reduced weight (from 6 to 4 lb); considerably reduced sheet metal requirements; ease of spray painting; improved strength and durability. *Cost:* materials cost same as original but tooling and maintenance costs considerably reduced.



J. Bishop & Co.

304L stainless tubing helped Atlas into orbit

The switch from 304 stainless steel seamless tubing to 304L seamless tubing (lower carbon content) is said to have been an important factor in the successful launching of the Atlas missile.

The tubing, part of a telemetering bulb (see photo above), had to withstand severe vibration fatigue at temperatures ranging from -80 to -380 F in an inert helium gas atmosphere. According to Lewis Engineering Co., the original 304 stainless tubing cracked; 304L met all requirements.

Many materials, processes used in

World's fastest jet plane

The Lockheed F-104 Starfighter shown below has set nine world records: 1) speed—1404.09 mph; 2) altitude—91,243 ft; and 3) time to climb—seven new records for 3000, 6000, 9000, 12,000, 15,000, 20,000 and 25,000 meters. Described by Lockheed Aircraft Corp. as a "lightweight" fighter, the plane measures 12 ft, 6 in. in height, 54 ft, 9 in. in length, and has a 24 ft, 11-in. wingspan.

According to Lockheed, the plane is designed to be light in weight; low cost; fast; maneuverable; and capable of mass production, fast assembly breakdown and easy accessibility. The many different engineering materials used in the plane are listed in the box on p 189. In addition to proven manufacturing techniques, the following fabrication innovations contributed to the plane's development:

Extrusion of integrally stiffened aluminum panels—To produce lighter, more efficient and smoother surfaces for air-intake ducts, Lockheed uses extruded integrally stiffened aluminum panels which are contoured into the desired shape by stretch forming. The accompanying set of photos (Fig 1) show the aluminum extrusion before and after it is stretch formed. The original extrusion is slit, flattened by biaxially stretching, and then stretch formed to the final configuration. Chem milling is then used to reduce the gage of the material because sufficiently thin material cannot be pro-

(continued on p 189)

This article is based on an entry in M/DE's recent "Best Use of Materials" competition.

MORE MATERIALS AT WORK

RCI EPOTUF EPOXY RESIN

"It has been essential in development of our transistorized warning light"— R. E. Dietz Company, Syracuse, N. Y.

Since 1840 the Dietz Company has lighted America — with everything from kerosene lamps to auto headlights. In developing a new compact warning signal light, the company was faced with the problem of protecting the circuitry. They needed a material with strength, low potting temperature, waterproof and non-conducting properties. Reichhold EPOTUF Epoxy met every specification. For superior insulation of miniaturized components, investigate RCI EPOTUF Epoxy Resins — REICHHOLD CHEMICALS, INC., RCI Building, White Plains, N. Y.

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Sebacic Acid • Ortho-Phenylphenol • Sodium Sulfite • Pentaerythritol • Pentachlorophenol • Sodium Pentachlorophenate • Sulfuric Acid • Methanol

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More informative ads

To the Editor:

Recently, we had occasion to contact several of your advertisers who indicated they could furnish plastic materials. Upon writing to three firms who advertised plastics to see if they could furnish parts as per our drawings, it was found that these firms were only materials suppliers (and that in large quantity) and could not fulfill our requirements. This caused some delay in finding a suitable source for the fabrication of our parts.

I think your advertisers could assist us greatly if they would indicate whether they are a materials supplier only or also fabricate finished parts.

While on the subject of advertisements, I would like to make a few more comments. I prefer more technical information, such as physical or chemical properties and specifications. The ads which use such nebulous terms as "lighter, stronger, wear resistant" leave me out in the cold. I want to know *how much* lighter, stronger, or wear resistant, and also, lighter or stronger than what? Machines are designed on the basis of numbers, not adjectives. If the numbers are not there, I am forced to go to a source which does supply the numbers.

CHARLES EUMURIAN
Principal Engineer
Mechanical Div.
General Mills, Inc.
Minneapolis, Minn.

Advertisers please note. As for readers, we suggest using the Directory Section of M/DE's Materials Selector *reference issue, where suppliers of materials and fabricators of parts are clearly differentiated.*

Unified science of materials

To the Editor:

Your timely editorial entitled "The New Unified Science of Materials," Feb '59, has been brought to my attention. I am enclosing an article that I wrote recently for the *Journal of Metals* which expresses the same viewpoint.

The difficulty in getting acceptance of our viewpoint from those traditionally interested in materials is that the orientation of both the professional societies and the educational curriculum has been toward the materials producer rather than the user. It is not enough to merely point out that there are more materials-conscious people in user companies. Those engaged in education must also be able to attract first-class people to a materials department or materials curriculum.

Very few of our young people realize how important materials are to society, nor do they recognize the challenging opportunities to be met in the development and use of materials. The science

of materials is difficult to make glamorous via the printed page. Young people of talent are more attracted to science because of the idea that the future of the world depends on it many are attracted to electronics because it is a branch met every day by the young adolescent.

Another point is that the greater part of research and development is now done by the materials-consuming rather than the materials-producing industry. We recently had a survey made of the published literature in the professional journals of science and engineering and found that with the exception of two glass companies, no leading materials-producing company did a substantial amount of research in either ceramics, metallurgy, polymer science, semiconductor technology or solid state physics, as measured by the numbers of scientific papers they published.

The industrial leaders in research in such fields are companies like General Electric, Westinghouse, and American Telephone and Telegraph, companies which must have exceptional materials if their products are to be competitive. Companies of this type, being materials consumers, benefit most from materials innovations. Innovation from the materials-producer point of view, on the other hand, usually displaces already profitable businesses.

J. H. HOLLOMON, Manager
Metallurgy and Ceramics Research Dept.
General Electric Co.
Schenectady, N. Y.

Welded steel tubing

To the Editor:

In your Apr '59 issue, p 10, standard sizes of welded steel tubing should have been stated as follows: cold rolled carbon steel, from $\frac{3}{8}$-in. o.d. (walls, 0.083 to 0.028 in.) to 6-in. o.d. (walls, 0.120 to 0.065 in.); hot rolled carbon steel, from $\frac{3}{4}$-in. o.d. (walls, 0.095 to 0.065 in.) to 6-in. o.d. (walls, 0.259 to 0.065 in.). Other sizes can be obtained on order and are produced by cold drawing.

Also, the last sentence of the "Towers" caption should have read: "By using welded steel tubing, tower manufacturers found they can build any shape tower—triangular, square or round—without sacrificing wind load properties." The published caption incorrectly implied that the *tubing* could be triangular or square.

JEHU R. DERRICKSON
Executive Secretary-Treasurer
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Cleveland, Ohio

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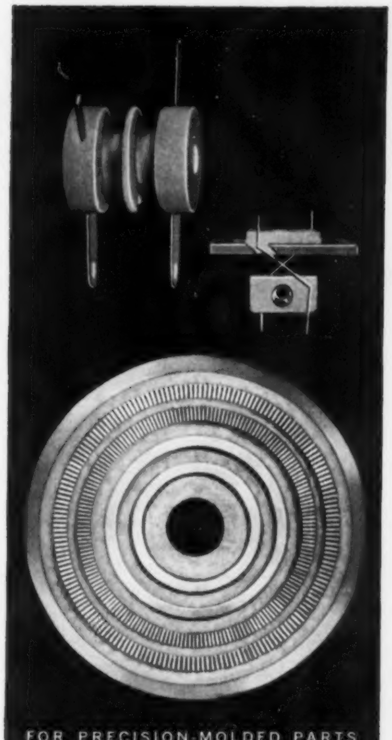
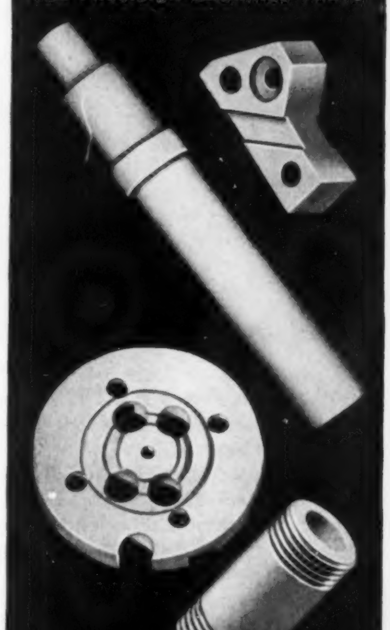


FOR PRECISION-MOLDED PARTS

FOR PRECISION-MACHINED PARTS



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PRICES AND SUPPLY

...AT A GLANCE

Greater availability of 'cleaner, tougher' steels will result from the recent installation of two new consumable electrode vacuum arc melting furnaces. The furnaces, a 24-in. unit installed by Vanadium-Alloys Steel Corp. and a 20-in. unit installed by Latrobe Steel Co., will be used to produce highly refined tool steels, bearing steels, ultra-high strength steels, high temperature alloys and reactive metals.

Consumption of plastics will quadruple in the next ten years, predicts Maurice Crass, Jr., secretary of the Manufacturing Chemists' Assn. Mr. Crass further predicts that structural applications will increase sharply over the next few years and that by 1966 the amount of plastics for structural uses alone will equal that used for all applications in 1958.

More zinc will be used in 1959 than was used in 1958, according to John L. Kimberley, executive vice president of American Zinc Institute. Mr. Kimberley bases his prediction on the following: 1) use of galvanized sheet steel has increased sharply; 2) automobile production will be considerably higher in 1959 than it was in 1958; and 3) federal highway programs will require large amounts of zinc in the form of hot dip galvanizing for guard rails, culverts, bridges, tunnels, etc.

Price of low density polyethylene has been increased 2¢ per lb for two formulations of natural material. New price is 35¢ per lb.

Aluminum use could set a new record this year if present levels continue through the second half. Thus far, consumption is about 40% higher than it was at this point in 1958. To meet this increased demand, Alcoa and Reynolds Metals Co. have boosted annual production by 40,000 tons and 30,000 tons respectively.

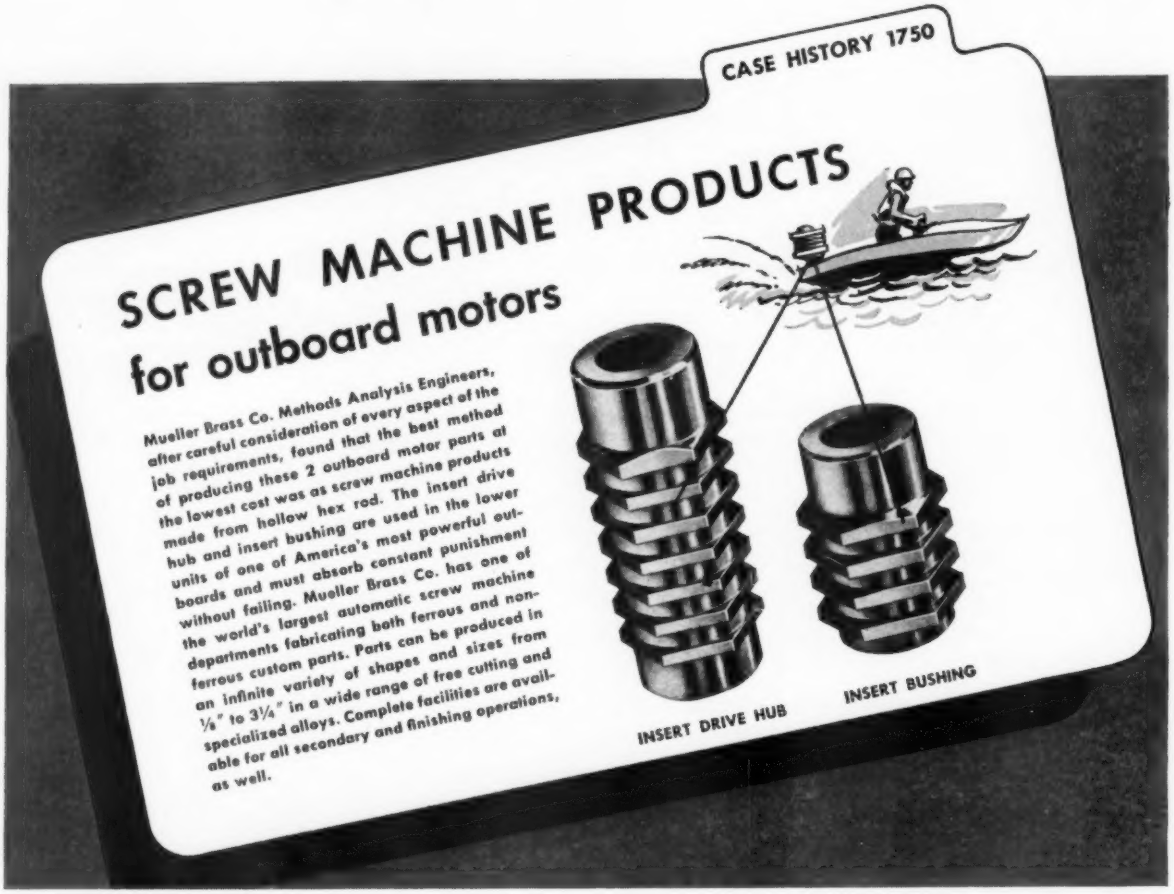
Fibrous potassium titanate —a relatively new lightweight thermal insulation material—has been reduced \$4.50 per lb by Du Pont. New price is \$7.50 per lb. According to Du Pont, in the 1300 to 2100 F range the material is "about twice as effective on a volume basis as any known thermal insulating material."

A new magnesium producer will enter the field in September despite the fact that both production and consumption decreased in 1958. The new producer, Alabama Metallurgical Corp., will have an initial annual capacity of 6800 tons. Dow Chemical Co., up to now the only U.S. producer, has an annual capacity of 83,000 tons. According to Dow, the competition will be "beneficial to both the magnesium industry and the nation." Current price, 36¢ per lb, is expected to remain unchanged; however, a price cut may result if a third producer enters the field—and a longstanding rumor has it that one of the aluminum companies might do so.

Price cuts on biaxially oriented polystyrene film and sheet materials were recently made by Plax Corp. Reductions amount to 3¢ per lb on all laminating, vacuum forming, pressure forming and general purpose grade materials from 0.001 to 0.020 in. thick.

Price of an important paint constituent—phthalic anhydride —has been reduced 4½¢ per lb by Monsanto Chemical Co. The material, now selling for 16½¢ per lb, is used in the production of alkyd and polyester paints, and a wide variety of plasticizers for vinyl and other thermoplastic resins.

two typical cases where MUELLER BRASS *determined the best and most*



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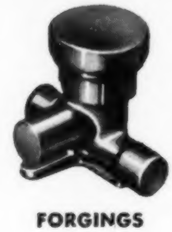

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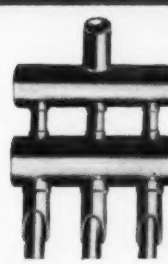

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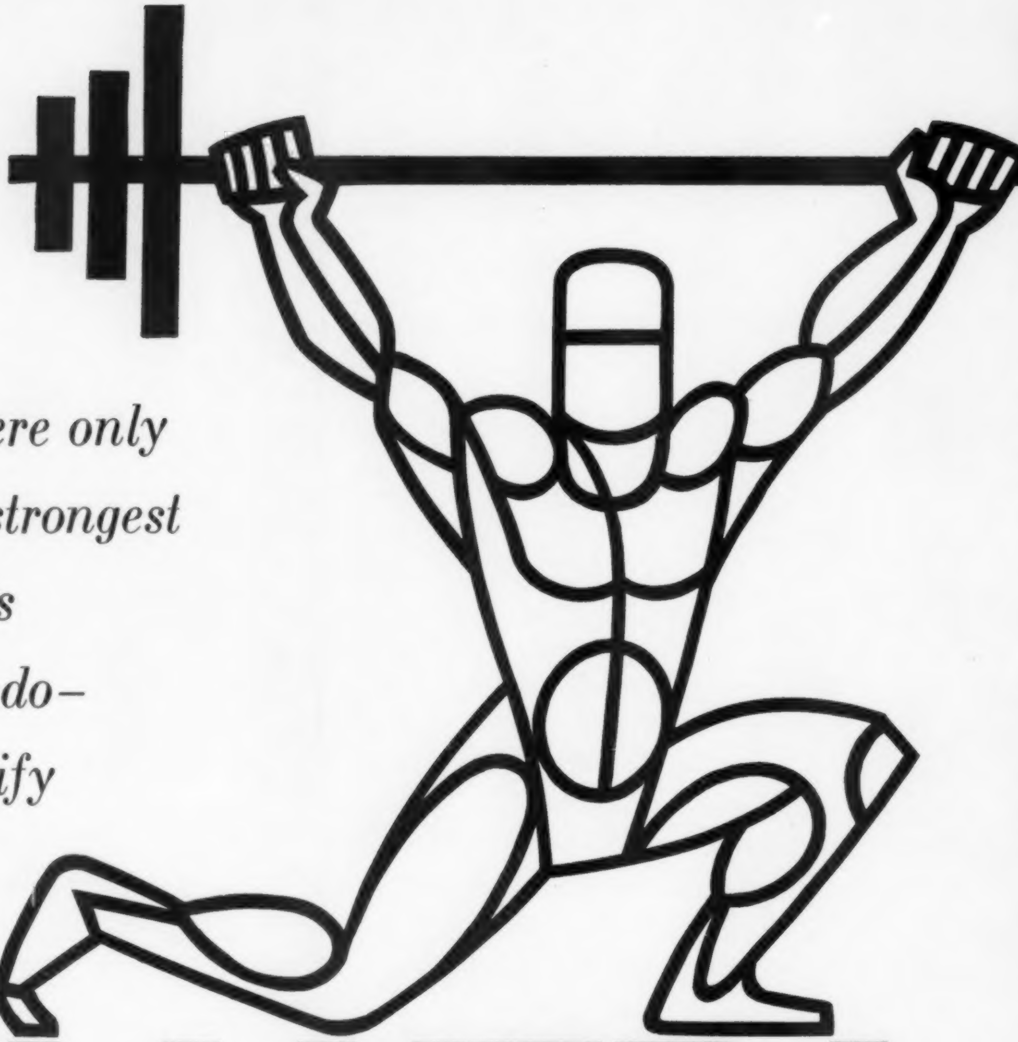

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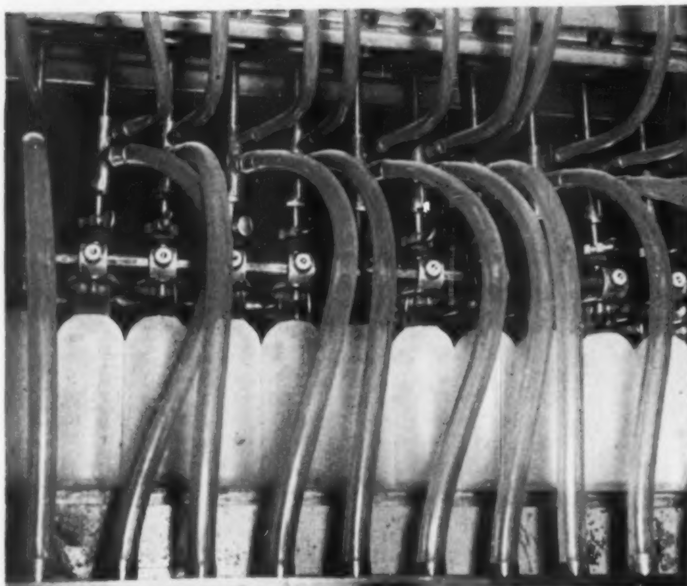

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DESIGNING WITH ALUMINUM

This is one of a series of information sheets that discuss the properties of aluminum and its alloys with relation to design. Extra or missing copies of the series supplied on request. Address: Advertising Dept., Kaiser Aluminum & Chemical Sales, Inc., 919 N. Michigan Ave., Chicago 11, Illinois.

NO. 30

ALUMINUM IN LOW TEMPERATURE APPLICATIONS

THE STRUCTURAL QUALITIES of aluminum and its alloys are actually improved at ultra-low levels of temperature, such as are encountered in the manufacture and handling of liquid gases. Tensile and yield strengths rise markedly, and percentage of elongation increases. As the lowest-cost metal capable of performing satisfactorily at temperatures below −150°F., aluminum is thus valuable to the rapidly expanding field of cryogenic applications.

Aluminum alloys also are unique among commercial metals in their combination of high strength-weight ratio, corrosion resistance, formability, weldability, reflectivity, and conductivity of heat and electrical energy. Also important for purposes of handling volatile liquids, aluminum is non-sparking, non-magnetic and non-toxic.

The requirements of commercial gas applications are filled chiefly by four industrial gases (see Figure 1). Oxygen, nitrogen, argon and helium—in that order of volume—comprise much the greater portion of commercial gas manufacture. Oxygen, nitrogen and argon are among the gases that are produced by liquefying air at −320°F. to effect a separation of each gas at its individual boiling point as a liquid. Equipment for this production can use, and has used, large quantities of aluminum alloy sheet, plate, extrusions, tubing and pipe.

These gas products, along with natural gas (mostly methane) are reduced by cooling and liquefaction to volumes only about 1/600 to 1/800 of their gaseous volume. *And because consumption by industry in both old and new applications currently amounts to hundreds of millions of cubic feet annually,* this reduction in handling bulk is of immense economic importance.

One of the latest military missiles, for example, consumes 420 cubic feet of liquid oxygen . . . 336 thousand cubic feet as gas . . . in a 90-second firing period. These liquefied gases may be stored and moved in aluminum alloy double-shelled insulated tanks, thus taking advantage of their extreme concentration in the low-temperature liquid state.

Double-shelled mobile liquid-oxygen tank, produced with Kaiser Aluminum alloy 5086. Used in fueling missiles, this tank is being loaded for transport by air.

FIGURE 1

SOME PROPERTIES OF COMMERCIAL GASES

	BOILING POINT OF LIQUID GAS (Fahrenheit)	LIQUID DENSITY AT BOILING POINT (Lbs./cu.ft.)	GAS DENSITY* (Lbs./cu.ft.)	APPROX. VOLUME INCREASE, LIQUID TO GAS*
OXYGEN	−297	71.2	0.089	799
NITROGEN	−321	50.4	0.078	650
ARGON	−302	88.02	0.1114	770
HELIUM	−452	7.82	0.0111	700
NATURAL GAS (Chiefly Methane)	−265	25.9	0.0447	580

*Gas at normal temperature and pressure.

FIGURE 2

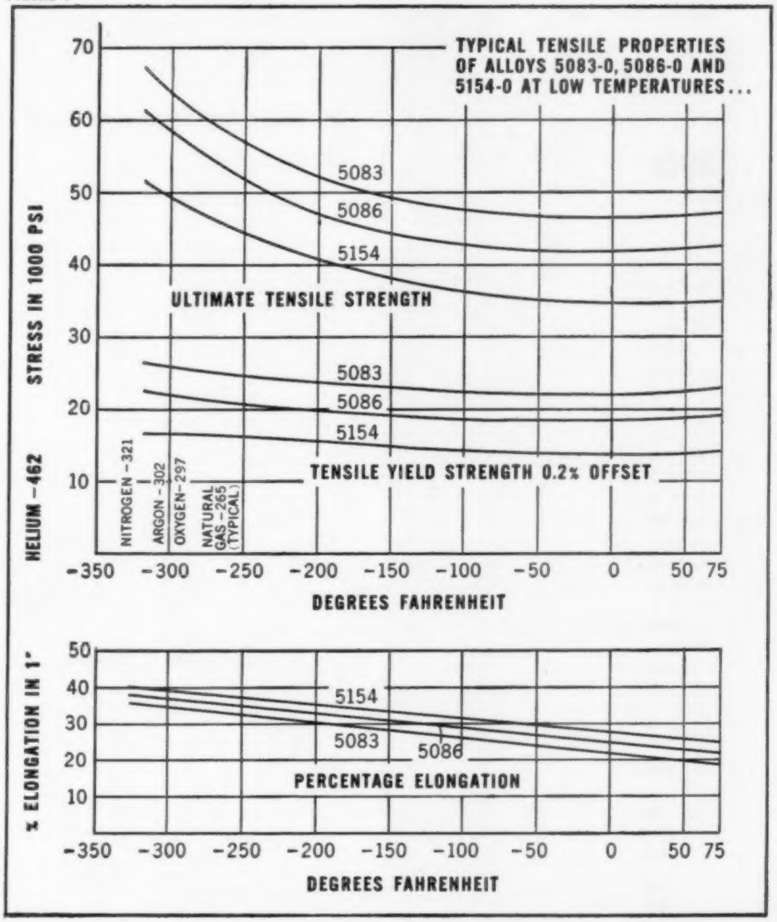
TYPICAL TENSILE PROPERTIES OF SOME ANNEALED ALUMINUM ALLOYS APPROVED BY ASME FOR UNFIRED PRESSURE VESSELS

ALLOY DESIGNATION AA	ASTM	ASME SECTION OR CASE NO.	TENSILE STRENGTH (psi) Ultimate	Yield	ASME ALLOWABLE DESIGN STRESS *VALUES (psi)	MINIMUM REQ'D WELDED TENSILE STRENGTH (psi)	PERCENT** ELONGATION
1100	990A	8	13,000	5,000	2,350	11,000	35
3003	M1A	8	16,000	6,000	3,150	14,000	30
3004	MG11A	8	26,000	10,000	5,650	23,000	20
5050	G1A	8	21,000	8,000	4,000	18,000	24
5052	GR20A	8	28,000	13,000	6,250	25,000	25
5154	GR40A	1174	35,000	15,000	7,350	30,000	27
5086	GM40A	1222	38,000	17,000	8,700	35,000	22
5083	GM41A	1247	42,000	21,000	10,000	40,000	22

* For metal temperature not exceeding 150°F.
** In 2 inch flat 1/16" gauge specimen at 75°F.

Nominal chemical compositions:
5154—Magnesium 3.5%, Manganese 0.05%, Chromium 0.25%
5086—Magnesium 4.0%, Manganese 0.45%, Chromium 0.15%
5083—Magnesium 4.45%, Manganese 0.75%, Chromium 0.15%

FIGURE 3

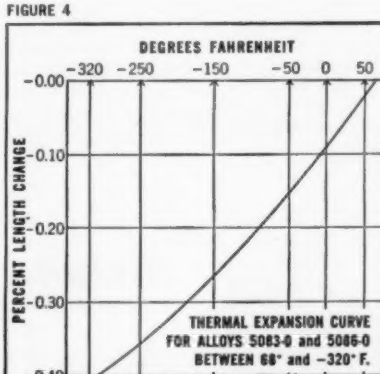


Several weldable aluminum alloys have been approved by the American Society of Mechanical Engineers as safe and suitable for construction of unfired pressure vessels such as are used in the handling of liquid gases.

Figure 2 tabulates typical tensile properties and the design stresses permitted by the ASME Code for some of these alloys, including high strength aluminum-magnesium compositions. All values shown are for metals in the annealed state. Kaiser Aluminum alloys 5083 and 5086 are the strongest ASME-approved aluminum-magnesium-manganese alloys that can be fabricated into these welded vessels by all normal methods, without need for stress-relieving or annealing. Both of these Kaiser alloys 5086 and 5083, when welded with 5183 filler, also meet the stringent "2T" bend test requirements for welds established by ASME for most other materials in these unfired pressure vessel applications.

The allowable design stress values shown are specified by ASME as acceptable for vessels and appurtenances from 150°F. down to –325°F. These permissible values are roughly two-thirds of the minimum guaranteed yield strength of the alloy at room temperature. Since the ultimate tensile and yield strengths of aluminum alloys increase as temperatures drop, the margin of safety rises still further at liquid gas temperature levels.

FIGURE 4



THERMAL EXPANSION COEFFICIENTS OF ALUMINUM ALLOYS AT LOW TEMPERATURES

Average Coefficients of Thermal Expansion ($\times 10^{-6}$ per degree F.)

ALUMINUM ALLOYS	68° to –200° F.	68° to –320° F.
1099	11.8	10.5
3003	11.2	10.0
5083	11.6	10.4
5086	11.6	10.4
6061	11.3	10.2
#304 Steel (Stainless)	7.7	7.4

The low temperature behavior of alloys 5154, 5086 and 5083 is exemplified approximately in Figure 3. Ultimate strengths increase by about 50% from room temperature to –320°F. Yield strengths rise by about 18%. Thus, at the –320°F. level, the yield strengths of these three high-strength alloys approximate 2¼ times the stresses allowed for pressure vessel design by the ASME Code.

Through the same temperature range, percentage elongation properties have been shown by test to increase 60% or more, reaching the magnitude of 40% elongation at –320°F.

This added strength and ductility contribute much to structural dependability against both mechanical shock and large temperature differentials in different portions of the same aluminum part or system.

The thermal contractions encountered in ultra-low temperature equipment are larger than those to be accommodated in ordinary design applications. For example, an aluminum member 25 feet long contracts by about 1¼-inch through the range from 68° to –325°F. Figure 4 shows these thermal expansion characteristics, as typified by aluminum alloys 5086 and 5083.

The low elastic modulus of aluminum also contributes to its suitability for low-temperature equipment by mitigating the adverse effects of thermal contraction. Thermal deformations cause much smaller increases or decreases of stress in aluminum parts than in equivalent stainless steel parts. The representative #304 stainless steel listed in Table 4 will contract only about 70% as much as the high strength weldable aluminum alloys, for any given drop in temperature. However, the aluminum alloys have an elastic modulus of about 10,300,000 psi, roughly one-third that of the steel. Because of this difference in elastic moduli, the stress changes resulting from thermal deformation through any given temperature change

CONTINUED ON NEXT PAGE ➡

Assembly of welded aluminum vessel for a liquid-oxygen generating plant. Such plants serve the steel and chemicals industries.

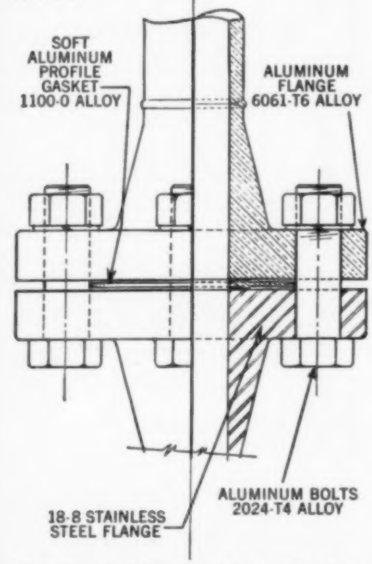
will be lower in the aluminum than in the steel.

One example of the advantages offered by this capacity for large elastic thermal deformations is the ability of aluminum alloy flanged joints, using 2024-T4 aluminum bolts, to maintain joint tightness under cyclical temperature conditions between 250°F. and −320°F. A bolt-loosening effect naturally occurs during the initial contraction of the pipe bore as it is cooled to liquid-gas temperatures, while the outer flange and the bolts remain relatively uncontracted at ambient levels. This tends to reduce gasket seating pressures. However, the loss of stress in aluminum bolts and flanges during thermal contraction of the pipe is much less than that occurring in equivalent steel parts. This ability to maintain stress during thermal deformations, along with the use of a soft aluminum profile gasket next to the bore, maintains adequate sealing while the flanges and bolts also cool. Since it often is desirable to bolt an aluminum flanged line to a stainless steel flanged line, for heat-dam purposes, this elastic property dictates that aluminum alloy 2024-T4 bolts should be used.

Metallurgical Research Data Now Available

Since most liquid-gas containers require a high vacuum between outer and inner shell to achieve the best possible insulating conditions, external pressure design charts have been developed by the Kaiser Aluminum Department of

FIGURE 5



Metallurgical Research for each of the high strength alloys. These charts, and other information on aluminum use in low temperature applications, are available to interested manufacturers.

For immediate attention to your request for these charts and other technical information—or for engineering assistance in your own applications—contact the Kaiser Aluminum sales office listed in your telephone directory.

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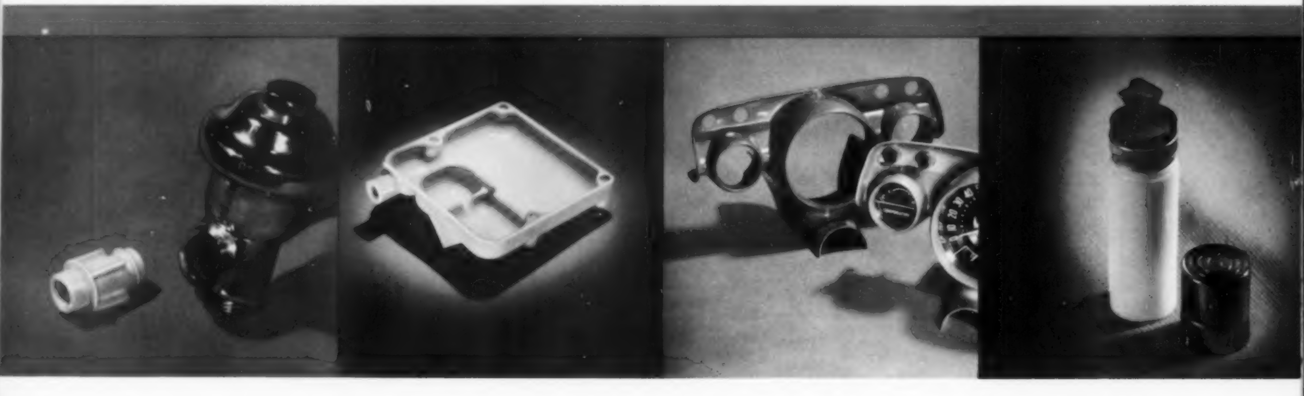
"Delrin" acetal resin is a highly crystalline, stable form of polymerized formaldehyde. This completely new material offers you metal-like mechanical properties, such as a high degree of strength and rigidity, plus other properties that metals do not possess.

The combination of properties offered by "Delrin" is unequaled by any other thermoplastic. For example, "Delrin" has high dimensional stability, tensile and flexural strength, resilience and toughness. Most importantly, "Delrin" retains these desirable properties under a wide range of service conditions—temperature, humidity, solvents and stress.

Over the past three years, "Delrin" has been

Typical performance and production advantages of "Delrin"



A brass part in a commercial flush valve was duplicated in "Delrin". This part operated perfectly for 18 months—the period of test —although it was completely and continuously immersed in water. The outstanding dimensional stability of "Delrin" under a wide variety of service conditions has also been proved, for example, in showerheads (continuously running water at 150°F.), and movie projector gears (run over 2,000 hours at ambient humidity).

This textile solution pan is ordinarily made of stainless steel. It must have resistance to oils and organic solvents, a clean, smooth surface; it also requires several threaded inserts plus other details. In normal quantities, stainless steel pans cost approximately $25 each. Injection molded in "Delrin", the cost was quoted at about $3 each. Testing showed that "Delrin" provided the required finish without machining, the needed solvent resistance, plus a weight saving of 75%.

A zinc die-casting mold was used to make this instrument cluster of "Delrin". Weight was reduced over the zinc component by almost 80%. In addition to manufacturing economies, further savings in assembly are indicated: self-tapping screws can be used, since the creep resistance of "Delrin" prevents loosening or stripping. These clusters can be molded in integral color or painted, and with a conventional mold would require little, if any, mechanical finishing.

Aerosol containers made of "Delrin" were shelf-stored for over a year; others stored for 3 months at 130°F. In both cases, the contents were still completely dischargeable. "Delrin" retains its strength and toughness for long periods, even when exposed to elevated temperatures and organic solvents. Equally important are the new opportunities for high styling opened by "Delrin"—the freedom to design in new shapes and integral colors to suit purchasing trends.

tested in hundreds of end-use applications by a host of industrial concerns. These tests have confirmed that parts made of "Delrin" can compete *on a performance and cost basis* with parts made of many metals, rubber, glass or wood. Of the various end-uses tested, 75% would normally be made of metal and another 10% of rubber, glass or wood. These tests have resulted in many applications of "Delrin" now being readied for commercial production—including gears, bearings, housings, containers, plumbing and hardware parts, pump impellers, "squirrel-cage" blowers, door handles, clothing fitments and many others.

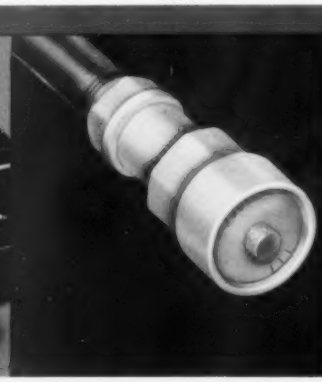
In addition to metal-like performance, "Delrin" offers you the manufacturing economies inherent in the production methods of the plastics industry. "Delrin" is easily injection molded, extruded, blow-molded or fabricated with conventional machine tools.

Illustrated below are a few of the applications of "Delrin" which have undergone extensive field service tests. The performance and economies listed were indicated during comparative evaluations made with materials in use at the time of the tests. These applications, together with additional data on the following page, may well suggest ways in which this versatile new engineering material can help *you* improve a product, lower its cost or develop new designs for your profit. Your inquiry is invited (see coupon on next page).

evaluated during three years of field tests . . .

Accessories usually made of metal, such as automotive window cranks and refrigerator door handles, can be economically mass-produced in "Delrin" by injection molding. "Delrin" provides required strength and rigidity. Integral colors, a variety of surface effects and functional details can be produced in one operation. Less weight, improved styling, dependable performance and potential cost savings are made possible by "Delrin".

Industrial components such as this "squirrel-cage" blower—as well as a variety of gears, bearings and other mechanical parts—have demonstrated the ability of "Delrin" to compete with various metals on a performance and cost basis. "Delrin" offers excellent fatigue life even when immersed in oil or water. Rapid production of lightweight, intricate components by the injection molding process can lead to substantial manufacturing economies with "Delrin".



Plumbing fixtures made of "Delrin", such as this showerhead, offer the manufacturer new styling and design advantages...and the home owner new latitudes in bathroom décor. Injection molded in integral color, fixtures made of "Delrin" assure builders and home owners of long-term dimensional stability, freedom from rust and mineral build-up. Modern in design, they are durable and dependable in service, and provide opportunities for potential cost savings.

Clothing fitments, such as zippers, clasps and snaps, are also readily and economically molded in "Delrin". Stiffness, toughness and resistance to heat, body oils and perspiration make "Delrin" a logical choice for such uses. Your customers would welcome the light weight, colorability and warm-to-the-touch benefits "Delrin" offers. Extensive field tests have demonstrated that "Delrin" is one of the most promising new materials available to the fitments industry.

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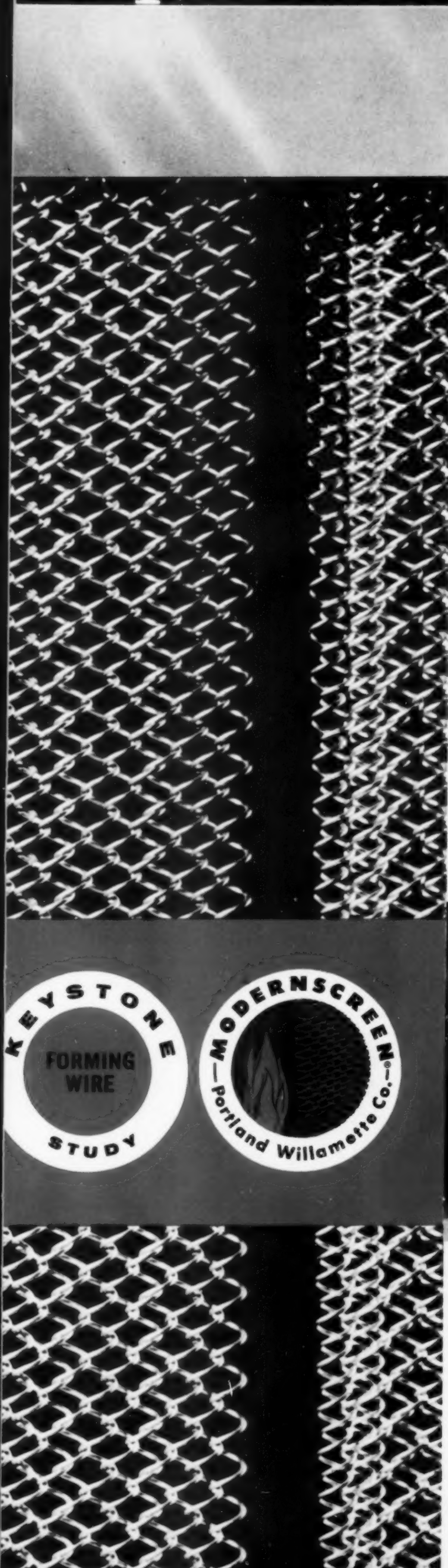
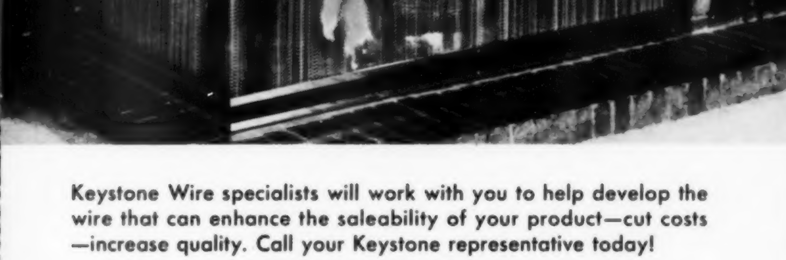
To volume produce fire screen like you see here, Portland Willamette Company, Portland, Oregon, employs incredibly accurate and complicated weaving looms. Successful operation of these automatic machines requires a perfect forming wire—a wire that is absolutely uniform throughout the thousands of feet in the long continuous coils. Modernscreen's wide range of finishes for fireplace screens demands a perfectly clean wire. It's made that way at Keystone and is shipped in moisture-proof fibre drums to protect it until ready to thread into the weaving looms.

Teamwork between Modernscreen and Keystone developed a wire with the necessary uniformity and surface qualities, and a packaging program to protect its extra clean finish. For these reasons, Modernscreen specifies Keystone Wire.





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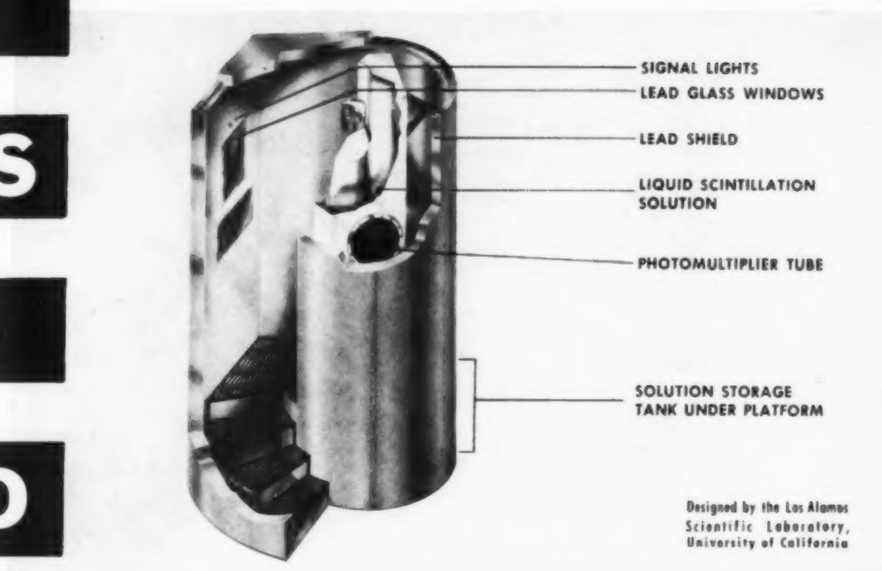
ACTUAL SIZE

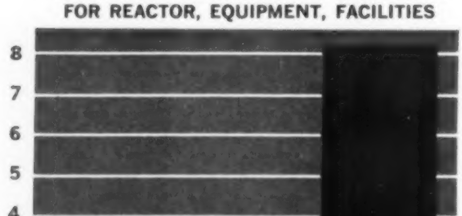
16 TONS OF LEAD



Provides The Shielding In This Walk-In HUMAN RADIOACTIVITY COUNTER

The need for instruments that can rapidly and accurately determine very small amounts of radioactivity in people and foodstuffs is urgent. The concern over world-wide fallout from nuclear weapons testing and the problem of efficient monitoring as part of power reactor development emphasize this need. In both cases, large numbers of people are potentially exposed either directly or through the wider, indirect hazard of contaminated food.

ESTIMATED CUMULATIVE EXPENDITURES FOR REACTOR, EQUIPMENT, FACILITIES



Source: NUCLEONICS, September, 1957, p. 33

This radiation counter was part of the United States exhibit at the Geneva Conference of Peaceful Uses of Atomic Energy. The 16 tons of lead provides a thickness of 3 inches of shielding in all directions. The shape of the shield resembles a snail shell. With this design, there is no direct "line of sight" from outside into the very sensitive gamma-ray counter . . . and eliminates the inconvenience and expense of a heavy door.

Lead, having the best shielding property of all common metals was chosen to provide maximum protection from gamma-rays with minimum weight and floor space. The metal's relative availability and economy was another factor. The cost of the vital 16-ton shield amounted to about 10% of the Geneva counter's total cost. The importance of this application and its potential is exemplified by the chart shown below.

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Carbide Tools. Adams Carbide Corp., 32 pp. No. 359. Information on a line of tungsten carbide tools, dies, tool tips and wear parts. **1**

No. 359. Information on a line of tungsten Brake Shoe Co., National Bearing Div., 8 pp. illus. Physical properties, general description, uses and chemical composition of bronze and copper alloys available as centrifugal castings. **2**

Gray Iron Castings. Auburn Foundry, Inc., 6 pp. illus. Describes facilities for producing gray iron castings. **3**

Carbon Steel Tubing. Babcock & Wilcox Co., Tubular Products Div., 8 pp. No. TB-419. Mechanical properties and size tolerances of electric resistance welded carbon steel mechanical tubing. **4**

Extruded Aluminum Shapes. William L. Bonnell Co., Inc., 6 pp. illus. Information on specially treated extruded aluminum shapes for marine applications. Information also on vinyl extrusions.

Aluminum Stampings. Bootz Mfg. Co., Inc., 4 pp. illus. Information on refrigerator parts made of anodized and embossed aluminum stampings. Information also on metal parts for washers, ranges and air conditioning units. **6**

Grain Size of Brass. Bridgeport Brass Co., 6 pp. illus. Tells how correct grain size of brass alloys can reduce finishing costs. Also describes how grain size of brass strip is affected by annealing and cold rolling. **7**

Beryllium Copper Alloys. Brush Beryllium Co., Pennrold Div., 12 pp. Chemical composition, specifications, physical and mechanical properties, heat treatment and weldability of three beryllium copper alloys. **8**

Finned Tubing. Woverine Tube Div., Calumet & Hecla, Inc., 24 pp. illus. Sizes, alloys, heat transfer data, and application data for integrally finned tube for heat transfer applications. **9**

Pure Chromium Metal. Chromalloy Corp., 4 pp. illus., No. 30. Suggested applications, chemical composition and fabricating characteristics of a 99.997% pure chromium metal called Iochrome. **10**

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Flame Sprayed Ceramics. Continental Coatings Corp., 6 pp. illus. Information on equipment used to flame spray ceramic coatings. Shows potential uses for flame sprayed ceramic coatings. **13**

TFE Tubing. Continental-Diamond Fibre Corp., 4 pp. illus. Electrical and physical properties, and sizes of extruded thin-wall TFE tubing. **14**

Heat Resistant Paints. Joseph Dixon Crucible Co., Paint Sales Div., 4 pp. Information on silicon-alkyd, aluminum-graphite and silica-graphite paints for use at temperatures up to 1000 F. **15**

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Gray Iron Castings. Gray Iron Founders' Society, Inc., National City-E 6th Bldg., Cleveland 14, Ohio, 75 pp. Contains an alphabetical list of members of the Society, a geographical listing of members, and a buyers' guide section. Write on company letterhead directly to Gray Iron Founders' Society.

Titanium. Harvey Aluminum, 36 pp. illus. Thermal properties, design data, machinability, corrosion and erosion resistance, fatigue properties and uses of titanium. **25**

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Machining Aluminum. Reynolds Metals Co., Box 2346, Richmond 18, Va., 32 pp. illus. Discusses turning, milling, shaping, planning, drilling, reaming, tapping, filing and sawing of aluminum. Write on company letterhead directly to Reynolds.

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Nonferrous Centrifugal Castings. Centrifugally Cast Products Div., Shenango Furnace Co., 8 pp. illus., No. 157. Specifications, chemical composition and physical properties of nonferrous alloys used in centrifugal cast-

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Plasma Arc Coating. Linde Co., Div. of Union Carbide Corp., 8 pp, illus. Describes a plasma arc plating process for applying coatings and fabricating shapes. Tells what materials can be applied and where they can be used. 50

Chemical Milling of Steel. United States Chemical Milling Corp., 2 pp, No. 8. Information on the chemical milling of carbon and stainless steel. Discusses the effect of chemical milling on the physical properties, surface finishes and tolerances of steel. 51

ABS Thermoplastic Sheet. United States Rubber Co., Royalite Plastic Products Div., 8 pp, illus., No. 59-1. Advantages, uses, and mechanical, thermal and electrical properties of ABS thermoplastic sheets. 52

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Centrifugally Spun Tubes. American Cast Iron Pipe Co., Special Products Div., 4 pp, illus. Centrifugally cast tubes furnished as-cast, rough machined or finish machined. 63

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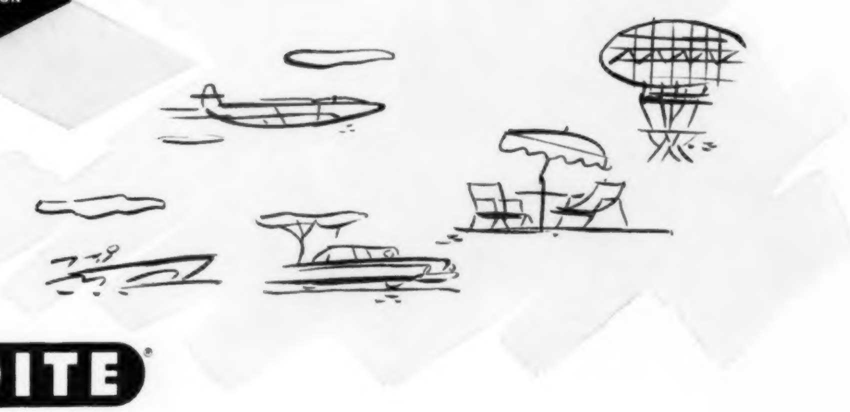

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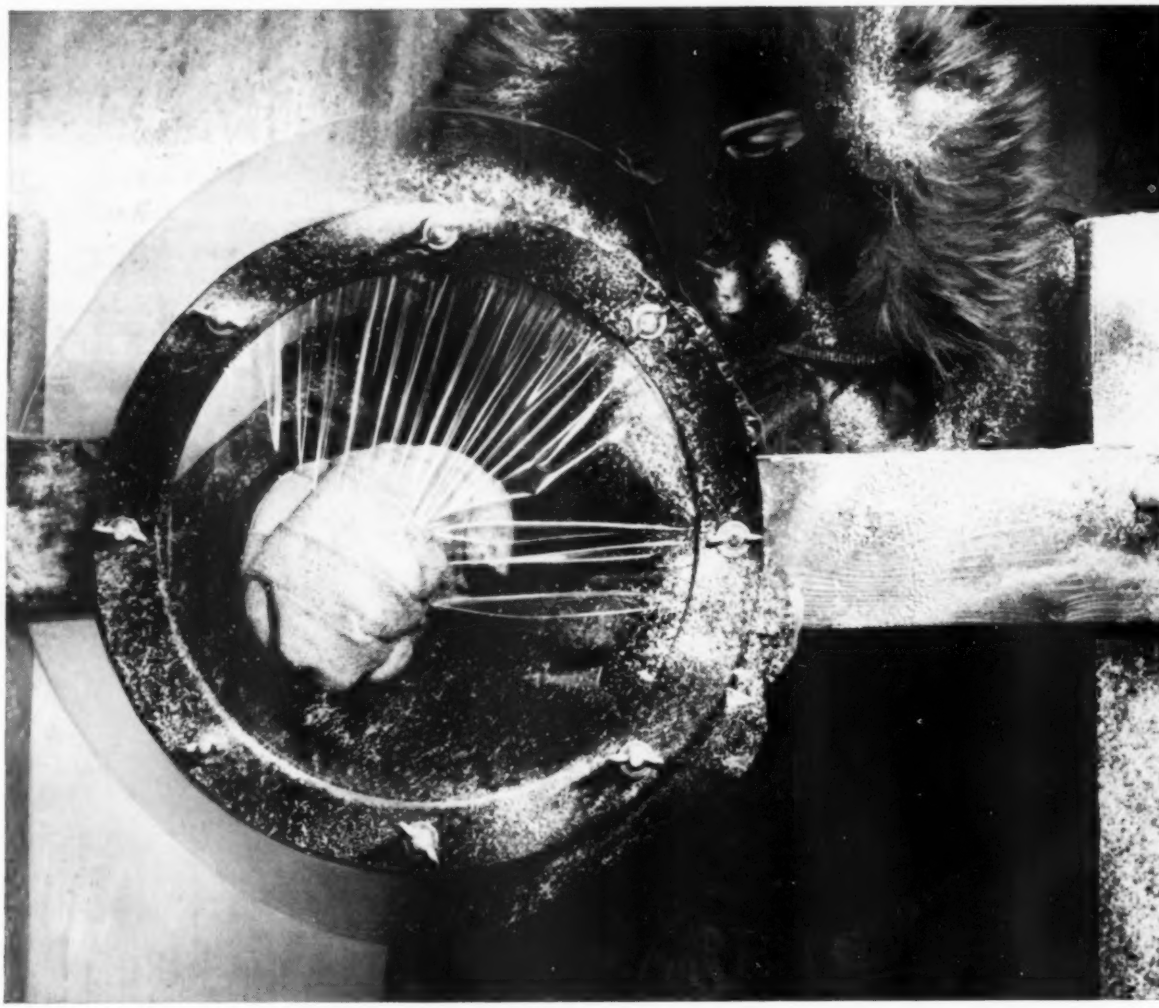

MYLAR® retains its high strength at -60°C.

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Weatherable "Mylar" Type W-2 resists ultraviolet light. This new film, with all the outstanding properties of regular "Mylar", is specially treated to withstand the sun's ultraviolet light. The film offers new design opportunities for outdoor applications.

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On an area basis, tough, thin "Mylar" often *costs less* than heavier, conventional materials. "Mylar" can be laminated, embossed and metalized, punched or coated. The film won't embrittle with age. "Mylar" is available in roll or sheet form in a wide range of gauges.

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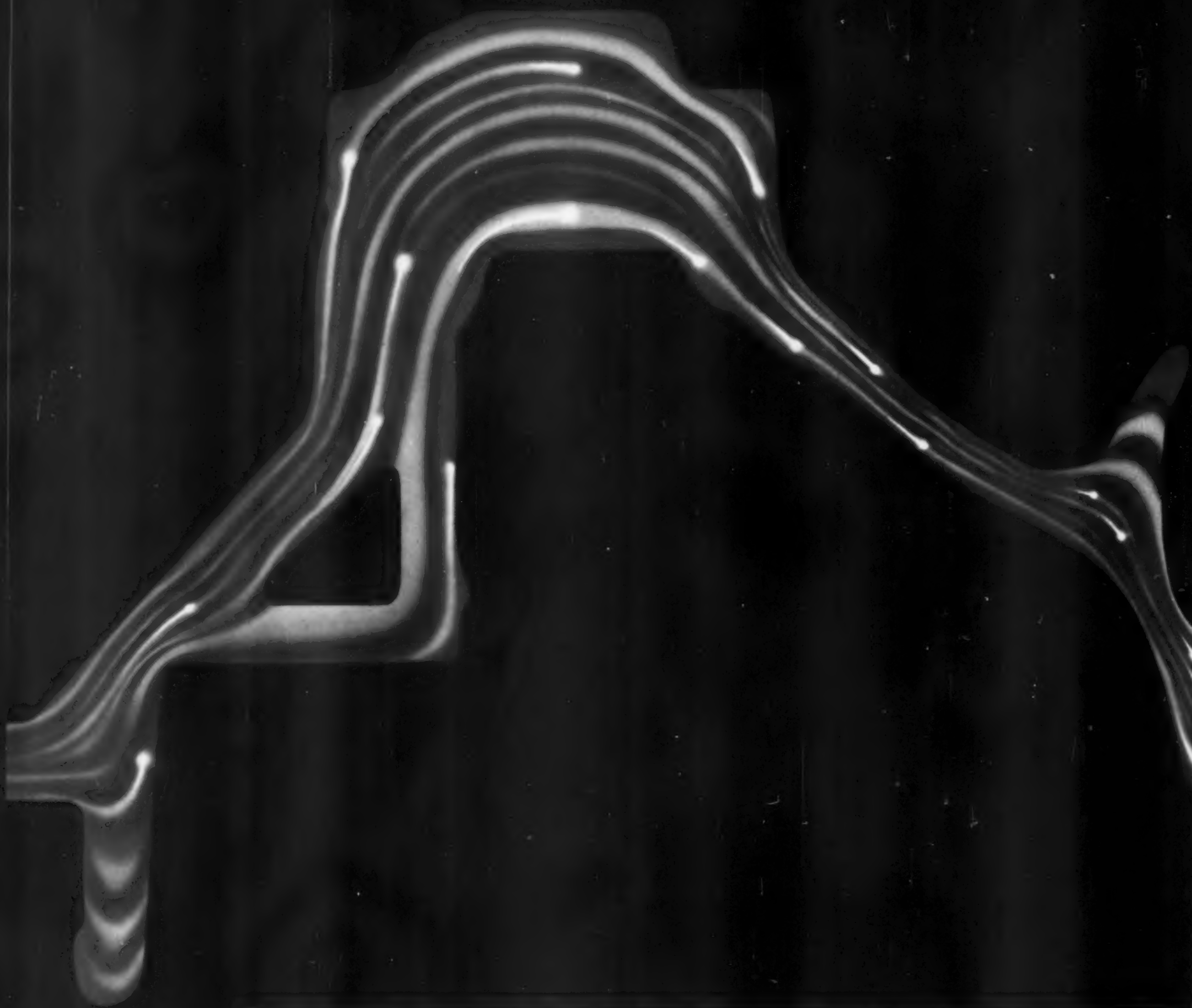

Fluid mapper pattern demonstrating liquid flow through a cross section of a Malleable differential carrier.

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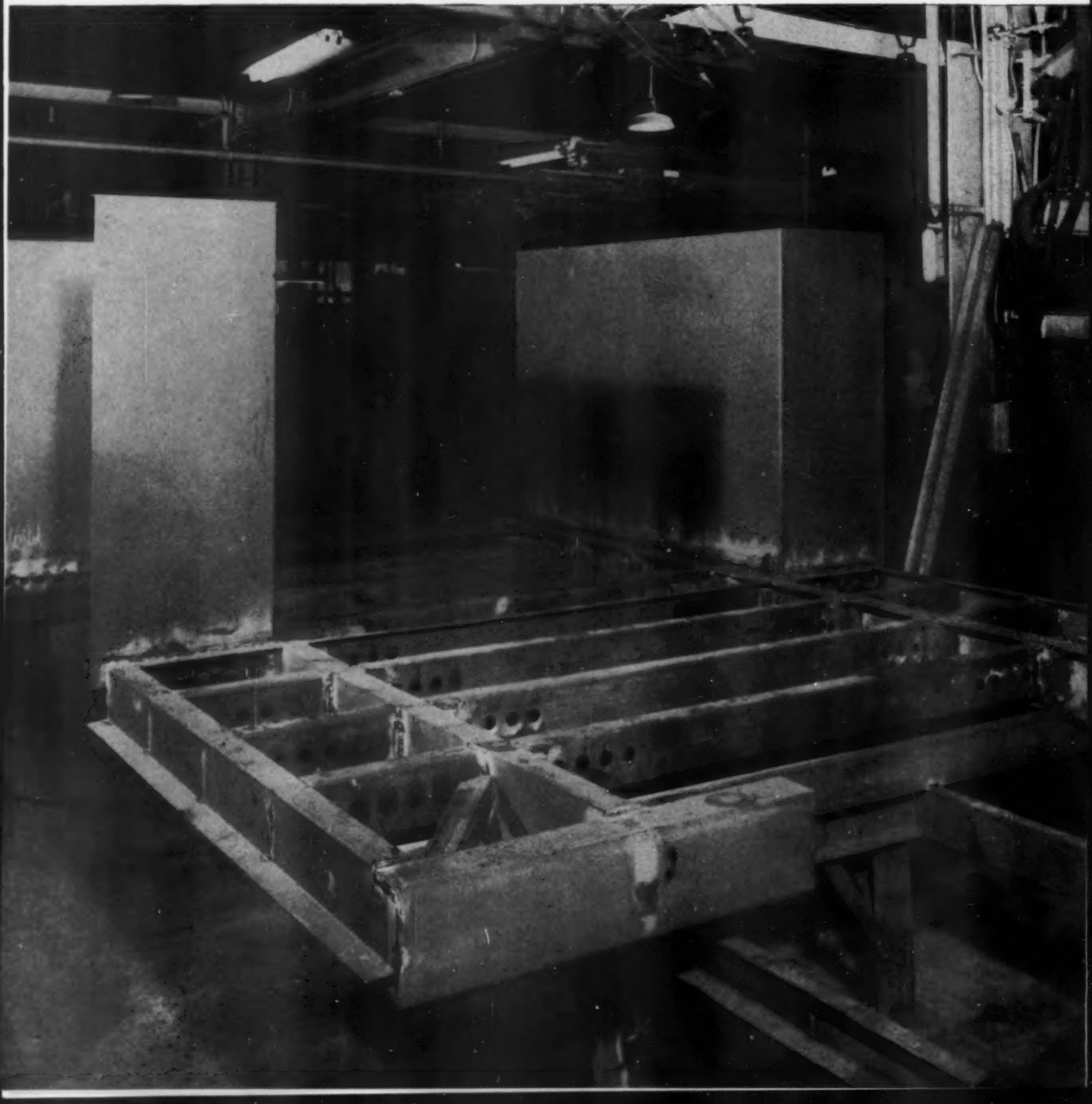
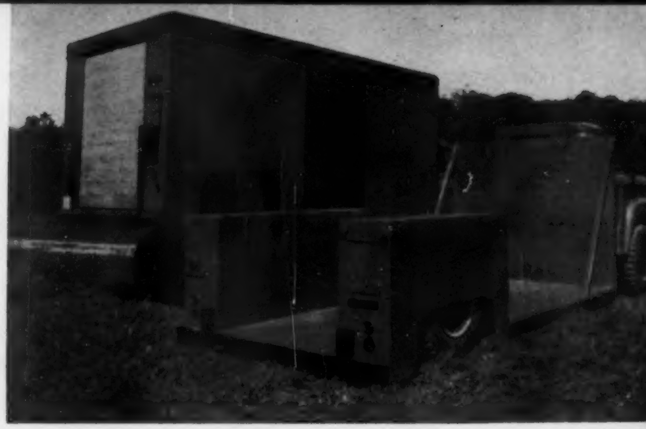
The Thompson Level-Loder raises and lowers to any height from curb side to 4½ feet. Hydraulic cylinders lift the body up and down in a vertical guide mounted on the truck cab. Thompson Trailer Corp., Pikesville, Maryland, a subsidiary of General American Transportation Corp., Chicago, introduced the new design.

It tilts .

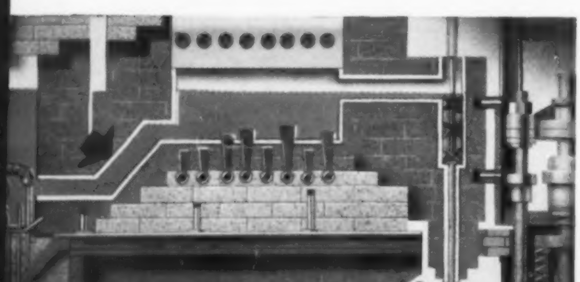


. it leans . . . . . . it hunches up and down

NON-STOP PRODUCTION OF LENS GLASS...

Where any metal but Platinum



PLATINUM DOES BETTER FOR LESS. In this hot end of the Bausch & Lomb continuous-flow furnace only platinum has the stamina to stand up long enough to return a profit. It is used as a lining material and in agitators and thermocouples.

It seemed preposterous at first. Line even part of a 5-ton capacity furnace with platinum? . . .

But the engineers at Bausch & Lomb had a case and proved it. The only *sure* way to contain glass at volcanic heat for month after month is in platinum.

The proof? Platinum melts at 3224°F (1770°C). Retains adequate strength at ophthalmic glass refining temperatures (2600°-2700°F). Doesn't dissolve in the melt to discolor, or degrade quality. Doesn't erodé or corrode in molten glass stream.

No other material provides the consistent purity essential to the economical mass-production of quality lenses.

The metal that masters molten glass may master a problem for you.

Where conditions involve high temperature and product purity, as in the production of lens glasses; or require peak catalytic efficiency, as in the refining of high octane gasoline; or a combination of severe corrosion and erosion must be met, as in the case of rayon production; or hard, highly con-

Platinum-lined five-ton furnace continuously fills molds with ophthalmic glass at Bausch & Lomb, makers of fine optical products. Furnace goes 18 months without shutdown. Glass must pass 23 quality tests.

would cost too much...

ductive surfaces, as in the production of printed electrical circuits; and many other products, the platinum metals have proved to be most economical.

Progress in research and development indicates a growing need for materials to cope with higher temperatures, higher pressures, more severe combinations of operating conditions . . . materials of proven ability to deliver long, trouble-free service life. To this end the unique potentials of the six platinum metals are being thoroughly explored on a continuing basis.

Platinum, palladium, ruthenium, iridium and rhodium *all* have unique properties, well worth your attention. Specialists are prepared to work closely with you in evaluating these metals for new commercial and scientific uses.

As a first step, write us for additional data on the unusual properties and successful applications of the six platinum metals and their alloys — indicating your field of interest or how we might be of assistance.

CAN THESE PROPERTIES OF THE PLATINUM METALS HELP YOU?

High Temperature Stability
Exceptional Chemical Inertness
Superior Wear Resistance
Peak Catalytic Activity
Low Vapor Pressure

The six platinum metals are:

PLATINUM · PALLADIUM · RHODIUM
RUTHENIUM · IRIDIUM · OSMIUM

INCO PLATINUM METALS DIVISION, The International Nickel Company, Inc., 67 Wall Street, New York 5, N. Y.

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In providing a secure, easily interchangeable attachment for Gravely rotary cultivators, Republic Nylok Studs are inserted into the adapter shown at left. The cultivator unit is then placed in position over studs, and nuts are applied, holding cultivator firmly in place. Republic Nylok Fasteners hold securely even under shocks from hidden stones, and vibration from the severe churning action of cultivator blades.

Republic Nylok® Fasteners Hold Securely Even Under Shocks of Rotary Cultivation

Finding a dependable fastening method for tractor-attached rotary cultivators presented a real challenge to Gravely Tractors, Inc., Dunbar, West Virginia. A fastener had to be found that would hold securely and give long, dependable service under the constant shocks and pounding of rotary cultivating. To meet these requirements, the company chose Republic Nylok Studs.

Republic Nylok Fasteners have a special nylon insert that assures positive locking at any position, even under severe shock, vibration, or tension. When the fastener is assembled, this nylon plug exerts pressure in a lateral direction, preventing all play, and utilizing the metal-to-metal contact of the opposing threads for locking.

Republic Nylok Fasteners provide maximum holding power under all conditions, whether seated or not; and they can be used repeatedly. One of their unique advantages is the "plastic memory" of the nylon plug—the tendency of the nylon to recover its original shape after assembly. This "growth" into the threads actually results in a tighter locking action, after a period of time, than when the fastener was first assembled.

The nylon insert is unaffected by age or cold, has high resistance to heat, and very low moisture-absorption rate. These are but a few of the advantages which led Gravely Tractors, Inc., to use Republic Nylok Fasteners on their advanced line of rotary cultivators. These and other advantages can pay dividends in *your* application, too. For full information, contact your Republic representative, or mail coupon.

FOR "BASIC" ADVANTAGES IN PLASTICS

Sometimes a customer will ask the Dow representative, "So you're basic in epoxy resins and other materials—what does that mean to me?" The answer: Many quality advantages accrue to the buyer from Dow's complete control of all chemicals that go into the making of resins and thermoplastics. During the developmental stage, this *basic* position makes for better-controlled research; in the manufacturing stage, it makes for greater accuracy in translating research developments into production. The end result: improved quality and uniformity that Dow customers can turn into *basic* selling advantages . . . as illustrated on these pages.

TV-TUBE DESIGN IMPROVED BY DOW EPOXY RESEARCH

For years TV designers have been at work on the improvement of TV set design to eliminate certain inherent disadvantages and provide a less bulky set. TV and glass engineers have created a new method of lamination that brilliantly accomplishes long-standing design objectives.

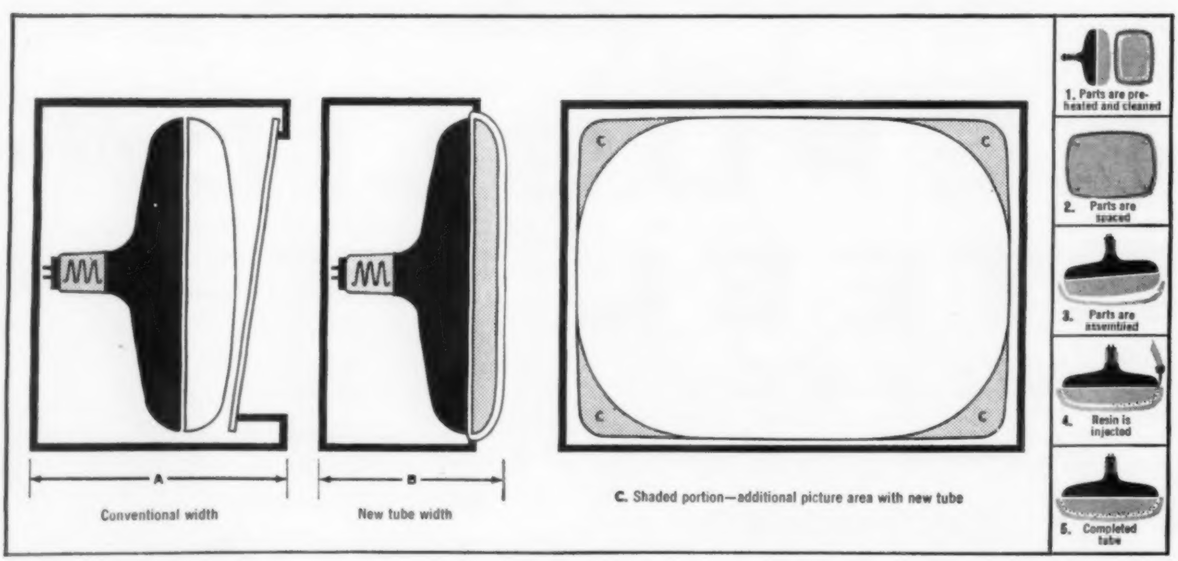
This latest example of the ability of Dow resin chemists to come up with major breakthroughs in plastics technology is a unique method of laminating a contour-fitted glass panel directly on the face of television tubes.

From the set designer's point of view, this allows reduction of the thickness of TV sets by inches and can provide new slim elegance for the set of tomorrow. Eliminating the separate panel of safety glass assures a *better, brighter picture* in two ways. First, the dead area between tube and conventional implosion panel is gone—entirely removing this dust-catching corridor. Second, a brighter TV picture results because elimination of the separate implosion panel increases light transmission and removes a distracting source of reflection between tube and panel.

Greater usable picture area on the tube is now possible also, because of the increased strength of the tube face provided by the new lamination with Dow epoxy resin. Up until now, TV tubes have been circular or oval in shape, masked by the set frame to appear square. With this new Dow lamination, the design of a virtually square tube becomes practical—and increased picture fidelity a reality.

This TV industry advancement was made possible in part by the *basic* position Dow holds in the manufacture of epoxies—including those used in making this new type of laminate.

The special facilities required for epoxy resin research—along with the know-how necessary to translate research results into production in minimum time—have been busy for years at the Dow laboratories in Midland, Michigan and Freeport, Texas. Right now, perhaps, they are working on problems of interest to your business. Why not investigate—today?



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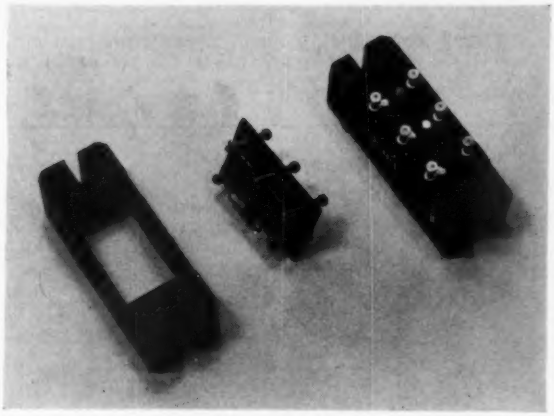
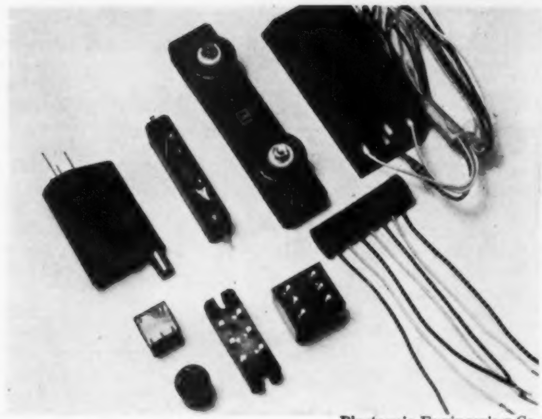


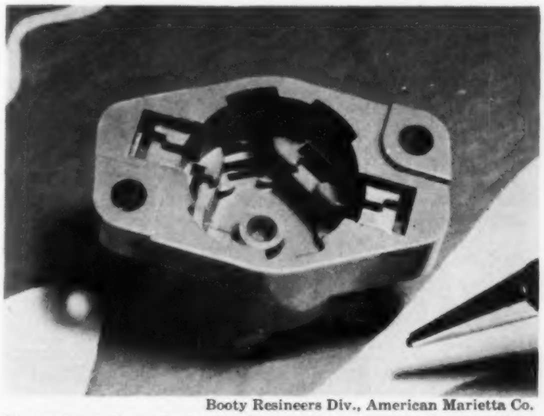


Plastronic Engineering Co.

Component cases *molded in epoxy become integral with encapsulated component. Photo at left shows the molded epoxy case, terminal board with diode assembly in place, and the complete encapsulated assembly. Photo at right shows variety of typical assemblies encapsulated in molded epoxy cases.*

These photos show some of the first electrical uses for

The New Epoxy Molding Materials



Booty Resineers Div., American Marietta Co.

Electrical housings *such as this one can be cured in 3-4 min.*

Epoxy resin parts made by economical, high-speed compression or transfer molding techniques are now a commercial reality. Here they are compared with DAP's, silicones and alkyds.

by Malcolm W. Riley, *Associate Editor, Materials in Design Engineering*

■ The inherent high dielectric characteristics, low moisture absorption, high dimensional stability, good mechanical strength, and excellent chemical resistance of epoxies can now be specified on an economical, high production basis.

As of April, both general purpose and high impact compounds were available (see box, p 73). General purpose compounds contain inert mineral fillers; high impact grades are reinforced either with chopped glass or synthetic (Dacron or Orlon) fibers. Although impact grades are available with glass contents as high as 50%, the 12% chopped glass compound is the only one for which property data are available.

Compounds are available in red, blue, yellow, green, black and natural tan.

Epoxies have always been relatively high priced—so are these compounds (see Table 1). Even with economical high speed production, the materials will probably be used only where their combination of high dielectric properties, dimensional stability, and extremely low moisture absorption is critical.

Key to the development—no-stick, short cycles

The two most critical problems overcome in developing the compounds were the inherent stickiness of epoxies and the relatively long cure times usually required.

Excellent adhesives in themselves, epoxies have always been tricky materials to release from molds. The new compounds have

TABLE 1—COMPARATIVE PROPERTIES OF EPOXY MOLDING COMPOUNDS[a]

Type	ASTM	Epoxy Molding Compounds: Mineral-Filled[b]	Epoxy Molding Compounds: 12% Glass-Reinforced[c]	DAP: Mineral-Filled: Typical Values[d]	DAP: Mineral-Filled: Mil-Type MDG	Silicone: Mineral-Filled: Typical Values[e]	Silicone: Mineral-Filled: Mil-Type MSG
ELECTRICAL PROPERTIES							
Arc Res, sec	D495	150-180	148	125-190	115 min	300-420	210 min
Dielec Str, v/mil	D149						
Short-Time		—	433	378	325 min	350-400	325
Step-by-Step		—	364	320-350	300 min	350-400	275
Volume Res, ohm-cm	D257	9×10^{15}	11×10^{13}	4×10^{13}	—	$>10^{13}$	—
Surface Res, ohms	D257	—	6.4×10^{13}	6×10^{9} [i]	5×10^{6} min	1×10^{12}	1×10^{9} min
Dielectric Constant	D150						
60 Cps		4.4	5.4	—	—	4.0-4.5	—
1 Kc		4.2	5.4	5.2	8.2 max	4.0-4.5	5.0 max
50 Kc		—	4.9	—	—	—	—
1 Mc		4.1	4.6	4.5	6.0 max	4.0-4.5	4.7 max
Power Factor[g]	D150						
60 Cps		0.011	0.038	—	—	0.003-0.013	—
1 Kc		0.019	0.038	0.039	0.14 max	0.002-0.011	0.015 max
50 Kc		—	0.023	—	—	—	—
1 Mc		0.013	0.024	0.040	0.12 max	0.003-0.006	0.01 max
MECHANICAL PROPERTIES							
Flex Str, 1000 psi	D790	11-12	15-16	8-10	6800 min	6.5-7.5	6 min
Flex Mod of Elast, 10^6 psi	D790	2.2	1.3[j]	—	—	1.0-1.3	—
Ten Str, 1000 psi	D638	8-10	—	4-5.5	4 min	3.5-4.5	2.5 min
Compr Str, 1000 psi	D695	25-26	—	18-25	18 min	16-20	15 min
Izod Impact Str, ft-lb/in. notch	D256	0.35	0.81	0.30-0.45	0.28 min	0.25-0.30	0.25 min
Rockwell Hardness	D785	M110	—	M107	—	M85-90	—
PHYSICAL PROPERTIES							
Specific Gravity	D792	1.85	1.80	1.65-1.70	—	1.8-2.0	—
Coef of Ther Exp, per °F	D696	2.6×10^{-5} [l]	—	3.5×10^{-5}	—	$9\text{-}10.4 \times 10^{-5}$	—
Heat Dist Temp (264 psi), F	D648	300-320	209, 278 min[n]	300-450	300 min[o]	>500	392 min[o]
Water Absorp (24 hr), %	D570	0.06	0.35[p]	0.2	0.7 max[r]	0.3-0.4[s]	0.50 max[r]
Mold Shrinkage, in./in.	D955	0.004-0.006	—	0.004-0.007	—	0.006-0.010	—
Post-Mold Shrinkage (hr, temp), in./in.		0.0003 (400, 302 F)	—	0.0005 (480, 257 F)	—	—	—
Cost, $/lb[t]		1.50-1.55	1.50-1.85	0.87-1.15	—	3.50-7.00[u]	—

[a] Values listed under MIL Type columns are average qualification requirements called out by MIL-M-14E. Types are as follows: Type MDG—DAP, mineral-filled, general purpose; MSG—silicone, mineral-filled, general purpose; MAG—alkyd, mineral-filled, general purpose.
[b] Range includes data on Hysol 8610 and Fiberite 2068.
[c] Tybon 5621-6; samples molded at 1000 psi, 300 F, 5-min cycle.
[d] Range covers asbestos-filled compounds produced by Durez Plastics Div., of Hooker Chemical Co., and Mesa Plastics Co.
[e] *Technical Data on Plastics*, Mfg. Chemists Assn., Feb '57.
[f] Hysol 6800, Houghton Laboratories, Inc.
[g] ASTM D150 power factor is the same as dissipation factor as used in MIL-M-14E.
[h] Values for Fiberite general purpose alkyd compounds.
[i] After conditioning 30 days, 100% RH, 158 F.
[j] Post-cured at 400 F for 1 day.
[k] D651.
[l] At 78-302 F; over temperature range of 78-140 F coefficient is 1.4 $\times 10^{-5}$.
[m] At 86-248 F.
[n] First value is after 2-hr post-cure at 300 F; second value is after 4 hr post-cure at 255 F; determined by LP 406B-1071.

self-releasing characteristics "built into the resin" so that no mold preparation is necessary. The only caution is that molds must be clean. (Particular care must be taken in cleaning a mold after using it for alkyds). In spite of this self-releasing characteristic, the compounds are said to provide good adhesion to inserts.

Cure times in the press range from 15 sec to about 15 min; 5 min is about average. Specific cure times depend on 1) mold temperature, 2) size and shape of the part, 3) whether preheating is used, and 4) whether the part is such that it can be ejected from the mold (early) and allowed to finish-cure out of the press. Cure times are said to be equivalent to those required for phenolic molding compounds.

Additional benefits are offered by the low molding pressures required. These may range from as low as 50 psi to 1500 psi (recommended molding temperature is about 300 F). Such low pressures facilitate accurate positioning of small, delicate inserts in a molding. Also, in many cases lower cost molds can be used.

How properties compare

From the property standpoint, epoxy molding compounds are probably most competitive with the DAP (diallyl phthalate) and silicone molding compounds.

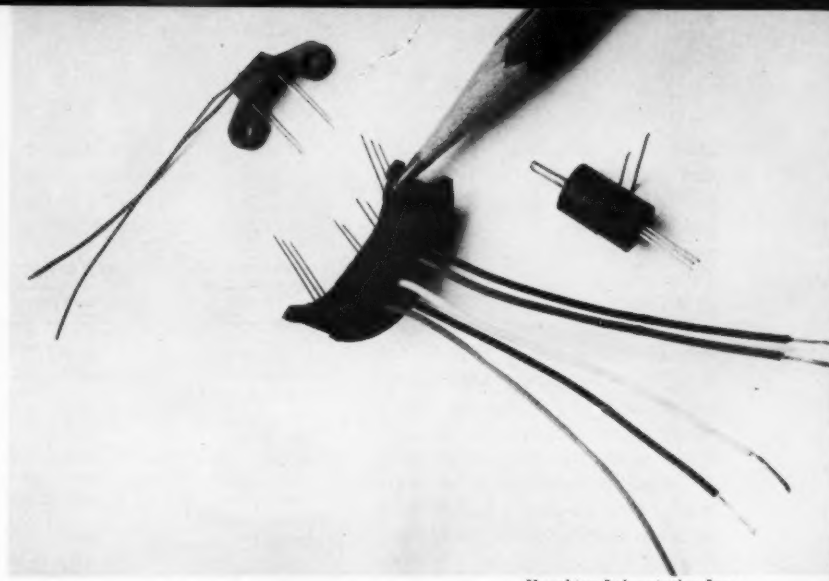
Table 1 compares properties of mineral-filled and glass-reinforced epoxies with typical values for mineral-filled DAP and silicone molding compounds. Comparable properties for mineral-filled alkyd molding compounds and a filled cast epoxy are also included for

Alkyd: Mineral-Filled		Cast Epoxy
Typical Values[e]	Mil-Type MAG	Mineral-Filled[f]
180	175 min	13-180
350-400	375	350-550
300-350	325	350-500
$0.6\text{-}3 \times 10^{13}$	—	75.5×10^{14}
—	—	—
6.0-6.5	—	—
—	6.2 max	4.1
—	—	—
4.2-5.0	6.0 max	—
0.035-0.040[h]	—	—
0.024[h]	0.04 max	0.004
—	—	—
0.013-0.015[h]	0.03 max	—
7-10	7.5 min	13
2.2-2.7	—	—
3-4[k]	3.5	12
16-21	15	21-27
0.30-0.35	—	0.31
—	—	M90
1.85-2.15	—	1.8
$1\text{-}3 \times 10^{-5}$	—	4.9×10^{-5} [m]
350-400	347 min[o]	250
0.08-0.10	0.50[r]	0.10
0.004-0.007	—	0.005
—	—	—
0.39-0.50	—	—

[o]As determined by L-P-406 Method 2011.1.
[p]7-day immersion in tap water.
[r]As determined by L-P-406 Method 7031.
[s]48-hr immersion.
[t]Range is for quantities of 400 lb or more.
[u]General price range. Specific prices not now available.

comparison. Qualification specifications under MIL-M-14E (Molding Plastics and Molded Plastic Parts, Thermosetting) are also given.

Epoxies vs DAP, silicones—Values from standard static tests, of course, cannot be used as the sole basis for materials selection. They can be used both to put the material in perspective, and for initial screening. Also, property data on epoxies are, as yet, somewhat limited. However, from the data available, it appears that the epoxies have a slight edge over

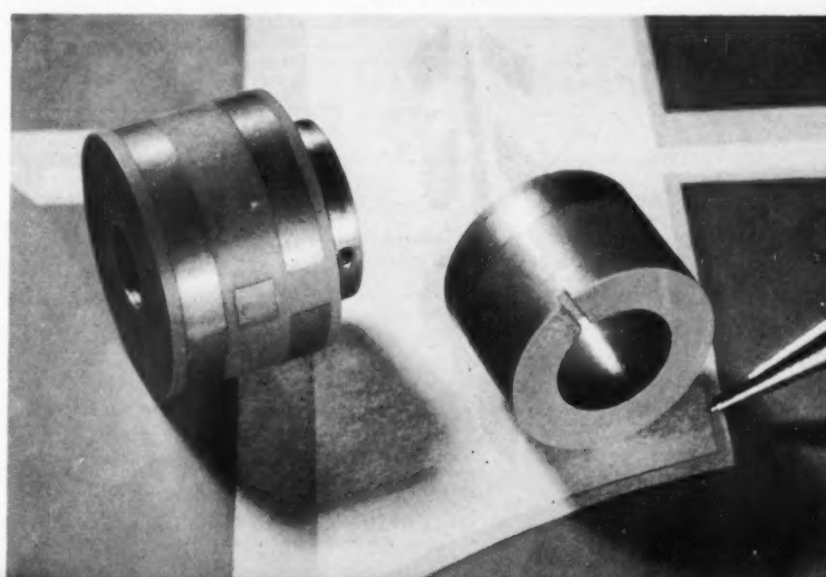


Houghton Laboratories, Inc.

Brush blocks and ferrite probe *molded by Unison Products, make use of good flow properties, good dielectric properties, low water absorption.*

Booty Resineers Div., American Marietta Co.

Electronic collector rings *for missiles incorporate intricate bronze and gold ring inserts and must be machined and finished to close tolerances.*



DAP's in electrical properties, and silicones appear somewhat better than the epoxies.

Mechanically, the epoxies appear to be definitely superior to silicones, and approximately equal to DAP.

Moisture absorption of epoxies appears to be lower than that of DAP and silicones, but specific comparative data showing effects of moisture absorption on electrical properties are not available.

From the standpoint of materials costs, as shown in the table, epoxies cost slightly more than DAP's (in general purpose grades) and much less than the silicones.

Thermal stability—Data on effects of heat on epoxies are quite spotty as yet. The 300-320 F heat distortion temperature given in Table 1 gives only a general comparative order of magnitude. Table 2 indicates the good retention of electrical properties on exposure to heat. Values do not show the effect of heat aging.

TABLE 2—HIGH TEMPERATURE ELECTRICAL PROPERTIES OF MINERAL-FILLED EPOXY COMPOUNDS[a]

Temp ➔	73 F	212 F	392 F
Volume Resistivity, ohm-cm	9×10^{15}	5×10^{13}	5×10^{10}
Power Factor			
60 Cps	0.011	0.032	0.35
1 Kc	0.019	0.028	0.084
1 Mc	0.013	0.016	0.019
Dielectric Constant			
60 Cps	4.4	4.9	5.9
1 Kc	4.2	4.6	5.1
1 Mc	4.1	4.3	4.3

[a]Data for Hysol 8610 and Fiberite 2068.

According to one producer, aging a 12% glass-reinforced compound for 1000 hr at 392 F resulted in no adverse effect on electrical or physical properties or dimensional stability. Weight loss was negligible.

Another producer reports that mineral-filled compounds show a weight loss of only 0.21% after 400 hr at 300 F, and 1.05% after 400 hr at 392 F.

Other epoxy molding compounds

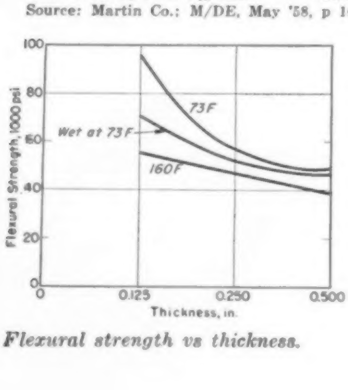
In summarizing epoxy molding compounds, brief mention should be made of a high strength structural molding compound, first reported here in Apr '58. Actually it is similar to so-called "premix molding compounds," in that it has a high glass content (65%), and reinforcing fibers are relatively long (½-1 in.). However, it has an epoxy rather than a polyester resin binder.

It differs in concept from the other new epoxy molding compounds in that it is not self-re-

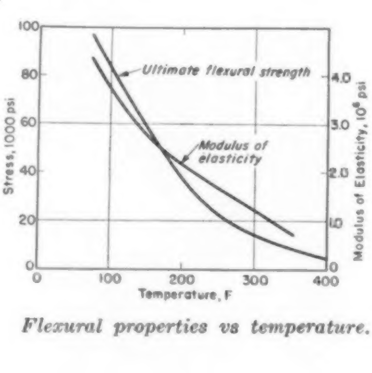
TABLE 3—PROPERTIES OF A HIGH STRENGTH EPOXY MOLDING COMPOUND[a] (Non-self-releasing)

Condition ➔	Rm Temp[c]		Wet at Rm Temp		160 F	
Thickness ➔	¼ In.[d]	½ In.[d]	¼ In.[d]	½ In.[d]	¼ In.[d]	½ In.[d]
TENSILE PROPERTIES (1011)[b]						
Ult Str, 1000 psi	31.9	30.3	39.0	29.8	27.6	32.2
Yld Str (0.2% offset), 1000 psi	30.7	27.3	29.5	28.5	27.5	31.4
Mod of Elast, 10^6 psi	3.39	3.04	3.0	3.24	1.98	2.40
COLUMN COMPRESSIVE PROPERTIES (1021.1)[b]						
Ult Str, 1000 psi	44.7	37.6	39.4	35.0	30.0	32.8
Yld Str (0.2% offset), 1000 psi	38.6	36.3	38.3	33.9	27.2	31.0
Mod of Elast, 10^6 psi	2.99	3.18	2.79	2.49	2.43	2.52
BLOCK COMPRESSIVE PROPERTIES (1021.1)[b]						
Ult Str, 1000 psi	—	50.0	—	54.7	—	39.3
Yld Str (0.2% offset), 1000 psi	—	49.6	—	54.7	—	41.8
Mod of Elast, 10^6 psi	—	2.25	—	2.69	—	2.12
FLEXURAL PROPERTIES (1031.1)[b]						
Ult Str, 1000 psi	55.6	48.5	51.7	46.9	47.6	39.4
Mod of Elast, 10^6 psi	2.44	2.71	2.44	2.75	1.97	2.44
	⅛ In.[d]		⅛ In.[d]		⅛ In.[d]	
Ult Str, 1000 psi	96.4		75.5		56.0	
Mod of Elast, 10^6 psi	4.42		4.13		2.59	

[a]Scotchply 1100. [b]Federal Specification L-P-406 test method given in parenthesis. [c]73.5 ± 2.5°F; 50 ± 5% RH. [d]Thicknesses are nominal.
Source: Martin Co.: M/DE, May '58, p 107.



Flexural strength vs thickness.



Flexural properties vs temperature.

End of a Long Wait

For more than four years there has been much speculation about epoxy molding compounds. Preliminary data sheets have been published . . . and one of the compounds discussed here has been in use for approximately a year and a half. But because of the developmental nature of the materials little useful design information has been available. This article is the first comprehensive report on the materials. As indicated in the box opposite, in addition to the two types on which data are available at this time, several other epoxy molding compounds are at various stages of availability.

leasing; consequently molds must be treated with proper parting agents. According to the producer self-releasing characteristics could not be incorporated without sacrifice in mechanical strength.

It can be compression or transfer molded at pressures ranging from 250 to 10,000 psi. Cure times are substantially longer than for the self-releasing epoxy compounds. For example, a ⅛-in. section required a cure of either 10 min in the press followed by a 16-hr post-cure, or 35-min cure in the press. One-inch sections require either 35 min in the press, followed by a 16-hr post-cure, or 70 min in the press.

Table 3 and the two graphs show typical mechanical properties obtainable with the compound. Typical flexural strength values range from 76,000 to 93,000 psi—a completely different order of magnitude than the 15,000 to 16,000 psi values obtainable in a 12% glass-reinforced self-releasing compound. Further property details on this high strength compound will be found in M/DE, May '58, p 106 (New Epoxy-Glass Molding Compound).

Booty Resineers Div., American Marietta Co.

Water impeller *(experimental) which could be used in deep water wells represents a possible mechanical use for the self-releasing compounds.*

Houghton Laboratories, Inc.

Intricacy of design *possible with the mineral-filled epoxies is demonstrated by these economically molded, diverse shapes.*

Here's Where to Buy Them . . . and What to Expect in the Future

Grouped below, by materials suppliers and tradenames, are the epoxy molding compounds commercially available as of Apr 1, '59. Also described briefly are other compounds which, according to the producers, are in various stages of development.

Booty Resineers Div., American-Marietta Co., Newark, Ohio. Two commercial (self-releasing) compounds: *Tybon 5921-5*—Mineral-filled (no property data available). *Tybon 5621-6, 5921-6*—12% chopped glass fiber-reinforced.

Future compounds include: 1) A 50% glass fiber-reinforced compound, which is said to be available, but on which no data are available as yet. 2) Compounds reinforced with nylon and polyester (Dacron) fibers; they are now in developmental stages. 3) A group of self-extinguishing compounds (both mineral-filled and reinforced) have been developed and are now available. According to Booty Resineers, the self-extinguishing characteristic is obtained by a radically new approach . . . "compounds do not contain chlorine in any form."

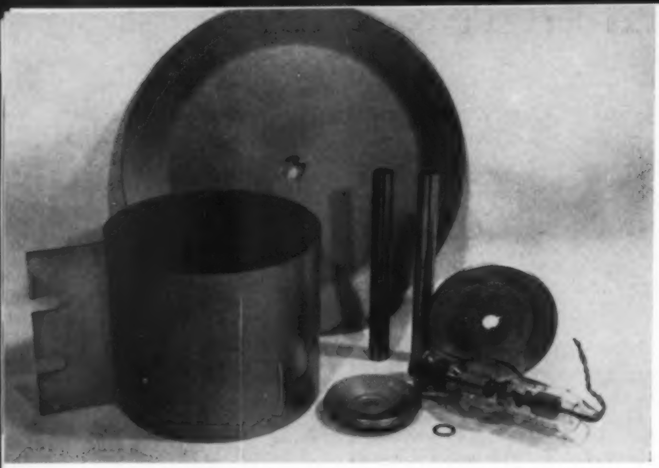
Fiberite Corp., Winona, Minn. Two commercial (self-releasing) compounds: *Fiberite 2068*—Mineral-filled. *Fiberite 2185*—Chopped polyester fiber (Dacron)-reinforced (property data now said to be available). *Fiberite 2175*—Molded coating and encapsulating compound (property data now said to be available).

Future compounds include: 1) Higher temperature resistant grades, designed for use at 500 F. 2) Higher impact grades making use of stronger reinforcing fibers.

Houghton Laboratories, Inc., Olean, N. Y. One commercial (self-releasing) compound: *Hysol 8610*—Mineral-filled, self-extinguishing.

Future compounds include a high impact (1-7 ft-lb per in. notch) glass-filled compound, available soon.

Minnesota Mining and Mfg. Co., St. Paul, Minn. One high strength compound (requires mold release treatment): *Scotchply 1100*—65% chopped glass fiber-reinforced.



Formed The forming of tungsten is similar to that of molybdenum in all respects excepting the temperature. However, grain size and shape, directionality, and uniformity of both temperature and thickness are more important in forming tungsten than in forming molybdenum. • For most forming operations on thin sheet, tools are heated to the range 600 to 1100 F. With stock thicknesses of 0.005 to 0.010 in., holes or blanks can be punched at 1100 to 1475 F. Satisfactory die-forming of tubular products from stock 0.010 to 0.015 in. thick requires uniform heating of the blank to prevent variable springback in the formed part. • Forming of heavier stock (0.100 to 0.200 in. thick) requires heating the blanks to 2000 to 2550 F, the temperature depending on the thickness. Punching of holes or circular blanks from stock 0.125 to 0.200 in. thick is done at 2200 to 2400 F. • Typical sheet metal products produced by these methods are shown at left. Included are x-ray tube anodes, formed tubes, washers, and resistance heating elements for high temperature furnaces. The dental x-ray tube shown contains a tungsten target cast in copper to permit liquid cooling of the target during operation.

Spun One of the most interesting developments in the fabrication of tungsten is spinning of shapes. Rolled plate and sheet thicknesses of 0.060 in. and 0.125 in. have been hot spun. Shown at left are cups, annular rings, and single and double-cone configurations. Contours comparable with those of rocket nozzles are possible. • It would be difficult to predict the many applications for parts fabricated in this manner. New product designs are possible in electronic tubes, in electrical contacts, in gyrocontrol components, in missiles, and perhaps in ordnance equipment.

Complex Tungsten Parts—

New Forming Methods Make Them Practical

by **R. W. Yancey,** *Consulting Metallurgist, Fansteel Metallurgical Corp.*

■ Tungsten parts with simple shape have been produced for many years, mainly by rolling and punching sheet or swaging and drawing wire. Now, the development of new hot working techniques—using high temperatures and high rates of deformation—makes it possible to press, spin, extrude and forge parts from tungsten, greatly broadening its field of application. As a result, because of its exceptional hot strength, tungsten shows real promise for some of the difficult rocket and missile applications of the future.

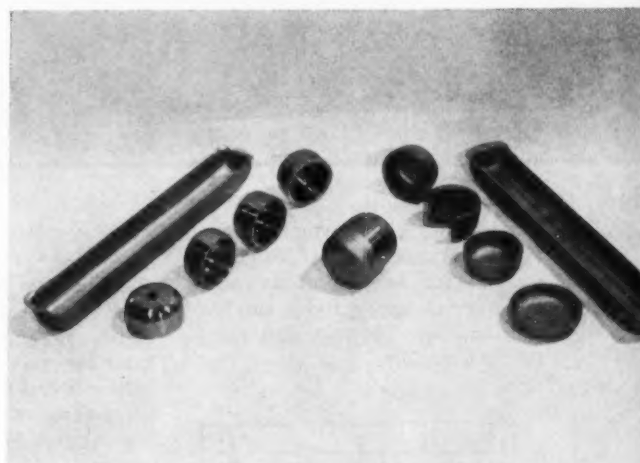
Properties of tungsten—and how they affect fabrication

Previous difficulties in fabricating tungsten have been related to its high melting point, excellent hot strength, and low ductility at normal temperatures. As shown in Fig 1, tungsten retains its tensile strength to high temperatures. The tensile strength of tungsten wire is about 25,000 psi at 3500 F, a temperature that is 500°F above the melting point of pure iron and about 800°F above the melting point of commercial steels. Though desirable for high temperature applications, this high hot strength makes it necessary to work tungsten at elevated temperatures. Cold working of tungsten, in the true metallurgical sense, is done at temperatures as high as 2550 F. By comparison, conventional materials

Forged Although sintered bars have been forged in flat sections since the working of tungsten began, the forging of tungsten shapes is just beginning. The ability to forge tungsten products into various shapes makes it possible to take advantage of the many desirable characteristics of tungsten that have not as yet been fully realized. The savings obtained by forging both small and large parts are greater with tungsten than with other metals which are more readily machinable. • Parts shown at right were made by forging swaged rod or pressed and sintered disks. The rod was upset in a series of operations; the heavy tungsten x-ray target was hammer forged from a flat cylindrical section.

Extruded Seamless tungsten tubing has been considered impossible to fabricate by extrusion, but recent advances in tooling and lubricants are promising. Tungsten can be forward extruded with a 70% reduction in area, suggesting the possibility of fabricating seamless tubing under proper conditions. An extruded tungsten tube is shown at right. Tungsten tubing in the hands of the electron tube designer might permit changing the design to obtain more reliable or higher powdered tubes having minimum dimensions.

Deep drawn Plate and sheet, ranging from 0.060 to 0.170 in. thick, are being deep drawn at high temperatures into the shapes shown at right. Product design possibilities include boats that may be used for evaporating metals, for firing ceramics and for electronic tube parts. Circular cups also offer many possibilities, e.g., a new type of x-ray tube anode which might reduce the overall size of the envelope, yet have the same heat dissipation at the same tube rating. • Drawn tungsten cups can be machined and ground to extremely close tolerances. This suggests their use as gyroscope rotors. A gyroscope rotor made from pure wrought tungsten sheet or plate would contain no voids, would be also 20% heavier than the tungsten alloys used at the present time, and would have a coefficient of thermal expansion about half that of the materials now used. If expansion is a factor in reliability, a pure tungsten rotor may offer considerable advantage in the construction and operation of directional control mechanisms for spacecraft.



are normally *hot* worked at lower temperatures. Fig 2 shows the effect of cold working on the strength of tungsten sheet. Hardness also increases as the material is worked.

Another factor which must be considered in the working of tungsten is the transition temperature. As shown in Fig 3, the transition from brittle to ductile behavior occurs considerably above room temperature—another factor that makes elevated temperatures necessary in working tungsten. Alloying is sometimes effective in lowering the transition temperature, and some alloys can be fabricated below the temperatures required for unalloyed tungsten.

Some of the physical properties of tungsten are given in an accompanying table. Tungsten has the highest melting point of all metals; carbon is the only element melting at a higher temperature. The density of tungsten is almost twice that of lead. The coefficient of expansion of tungsten is about one-third and the modulus of elasticity roughly twice that of iron.

Of particular importance to

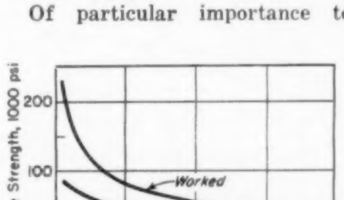
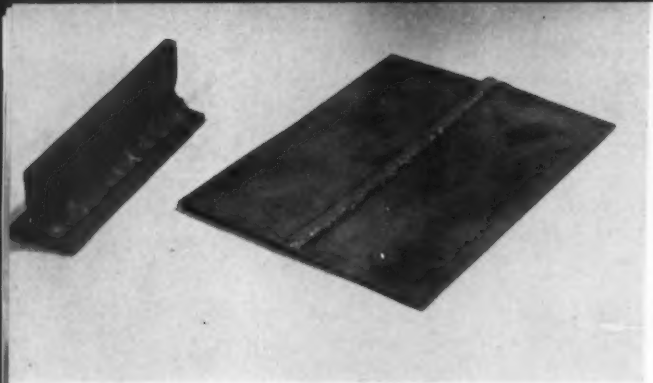
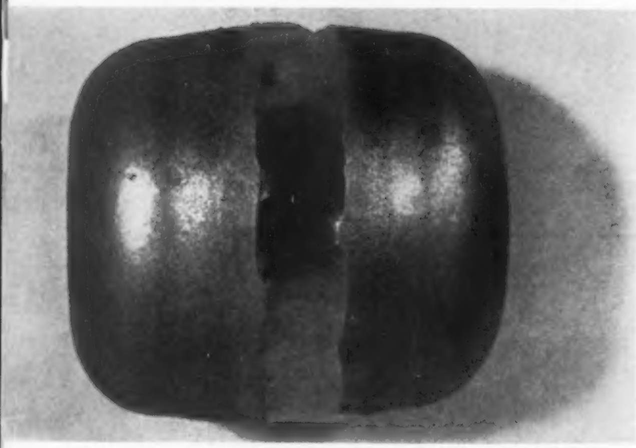


***Fig 1**—Tensile strength of tungsten is retained to high temperatures.*



Welded Although ductile tungsten welds may some day be commonplace, the present state of development leaves much to be desired. The weldments shown were made by fillet welding tungsten plate at 90 and at 180 deg. Inert-gas arc welds and electron beam welding may find usage soon in cases where no impact or bending stresses are present. Before extensive use is made of tungsten weldments for structural members the transition temperature of the metal must be lowered. Some hope lies in the tungsten-rhenium alloys recently developed.



Brazed Selection of a metal or alloy for brazing tungsten components varies with the temperature at which the part operates. Tantalum foil, 0.001 in. thick, can be used to spot-braze tungsten sheets for service at high temperatures. For lower operating temperatures, gold, gold-nickel-copper alloys, silver, copper or nickel can be used. Brazing is usually performed in hydrogen or cracked ammonia atmosphere furnaces. A possible application is the brazing of tungsten cups to form radioactive isotope containers. Shown at left is a unit of this kind brazed with pure gold, which has the same density as tungsten. • *Riveted*—Rivets of tantalum or molybdenum can be used in assembling structures larger than electronic tubes. High temperature furnace assemblies, for instance, can use this type of construction when the proper atmosphere is provided. For structural parts of aircraft or missiles, riveting will undoubtedly be selected as the assembly method.

fabricability are thermal conductivity and specific heat. Tungsten cools rapidly because of its excellent thermal conductivity and low specific heat. Thus working must be done rapidly.

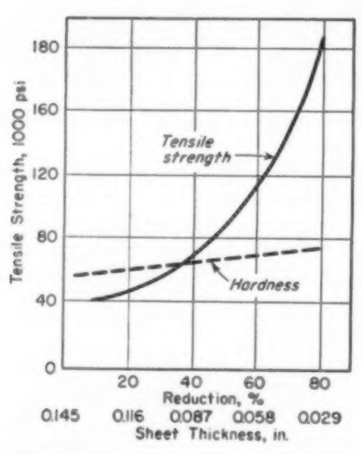


Fig 2—Tensile strength and hardness of tungsten are increased by working at temperatures up to 2550 F.

These mechanical and physical properties show that tungsten must be fabricated at high temperatures at high rates of deformation. The work-piece must enter the tools and be withdrawn before it can cool below the transition temperature. Types of tooling suitable for fast working are swaging dies, wire drawing dies, crank presses or high speed hydraulic presses, rolling mills and spinning lathes.

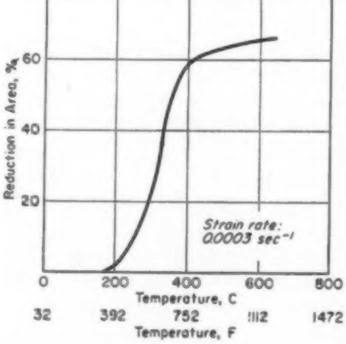
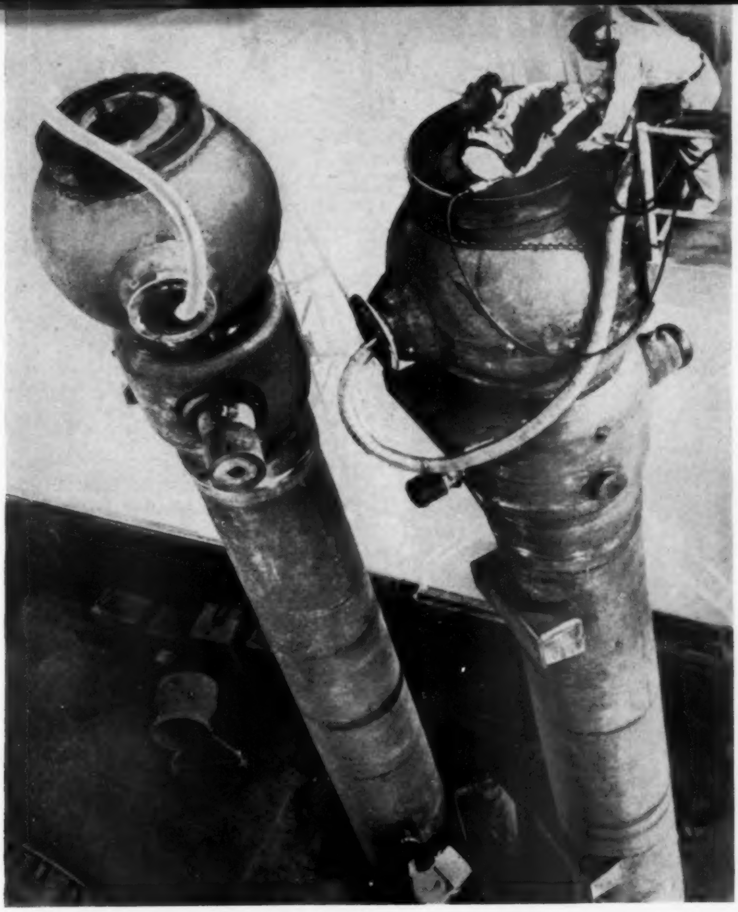


Fig 3—Transition temperature of tungsten is considerably above room temperature.

PHYSICAL PROPERTIES

Density, lb/cu in.	0.697
Melting Point, F	6170
Ther Cond, Btu/hr/sq ft/°F/ft	
1340	48
3140	64
4580	73
Coef of Ther Exp, per °F[a]	
85	2.47×10^{-6}
1885	2.88×10^{-6}
3685	4.03×10^{-6}
Specific Heat, Btu/lb/°F	
68-212	0.034
1830	0.367
Electrical Resistivity, microhm-cm	
68	5.5
2190	40.4
4350	85
Mod of Elast in Tension, psi	$50\text{-}60 \times 10^{6}$
Ther Neutron Capture	
Cross Section, barns/atom	19.2
Emissivity, w/sq cm	
1340	0.603
3140	24.0
4580	117.5

[a]Wire.



Feedwater heater *uses standard hemispherical steel head shapes to eliminate flanges and bolted gasket joints.*

Designing with Head Shapes Can Save You Money

The main requirement: design the part to include a surface of revolution. And don't forget that the standard head shapes available can be modified by flame cutting and welding.

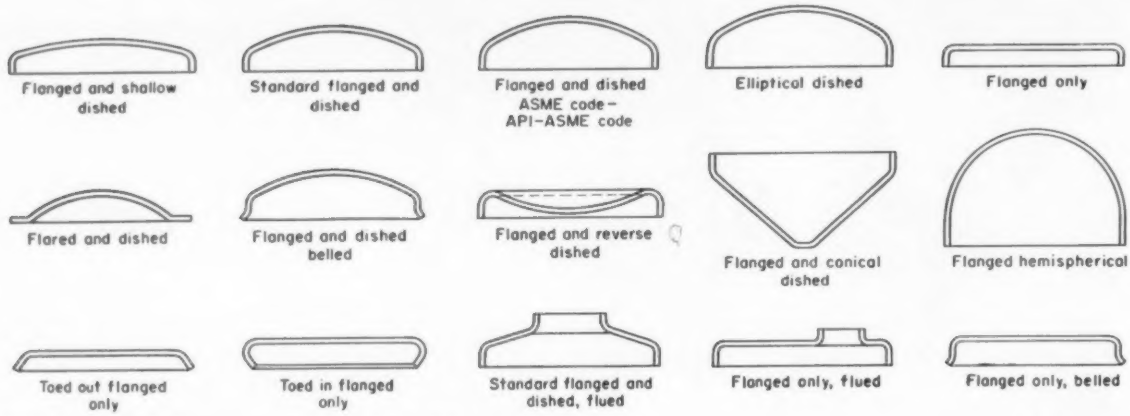
by Herbert A. Ottey, *Lukens Steel Co.*

■ Head shapes are commonly thought of merely as structural parts forming the ends of storage tanks and pressure vessels. But today, whether used in basic form or modified, standard head shapes are being used in a variety of ways to simplify design, cut fabrication costs, and increase operating efficiency.

Basically, a head shape is a surface of revolution. Therefore, any portion of a machine that comprises such a surface, or that can be designed as a surface of revolution, is potentially the spot for a head shape. Applications include such dissimilar items as safety guards on grinding wheels, turntable bases for fire-engine aerial ladders, and ventricular circuit breakers for electric power plants.

Advantages of designing with head shapes

- By incorporating a prefabricated shape in a design, considerable production time can be saved. The shop starts with a semifinished product rather than a raw material.
- Because head shapes can often be supplied from stock, less inventory need be carried on components needed in volume.
- Use of a semifinished product reduces the equipment needed, often enabling designers' shops to avoid purchase of special equipment needed to fabricate that part of the product.
- Uniform structural strength is assured. Since head shapes are spun or pressed from steel plates, they have a dense, homogeneous structure free of sand pockets and blow-holes.
- Steel plate construction often results in a lighter part than a casting or combination of casting and built-up structure.
- Dimensions are uniform, to fairly close tolerances, and proper design can eliminate or reduce machining time. Dimensional accuracy also facilitates assembly.
- Since large one-piece parts are used, fewer joints or seams are required. Thus, riveting or welding expense and time are minimized.



***Standard head shapes** are produced in 15 different types.*

SOME MATERIALS USED FOR HEAD SHAPES

Material	Condition	Mechanical Properties[a]		
		Ten Str, 1000 psi	Yld Str, 1000 psi	Elong (in 2 in.), %
STEELS				
T-1	Quenched, Tempered	115-135	100[b]	18
9% Nickel	Double Normalized, Tempered	90[b]	60[b]	20
Tricent	Heat Treated	280-320	245	10
H-11	Heat Treated	290	240	8
E4340	Heat Treated	260	217	8
TITANIUM ALLOYS				
6 Al-4V	Heat Treated	170	150	6-8
13 V-11 Cr-3 Al	Heat Treated	180-200	170-190	3-5

[a]Tensile and yield strength depend on a number of factors. These are typical values.
[b]Minimum.

• Pressed or spun head shapes have a fairly smooth, well-finished surface.

Available forms—and how they can be modified

The 15 basic head shapes are shown in the accompanying drawings. Although many applications require use of the entire head, others can be developed in which parts of the head are used effectively; modifications are made by flame cutting to remove material or by welding to add material.

Flame cutting — Basic head shapes are often modified by flame cutting to:

1. Make holes or remove portions of the head.
2. Obtain semicircular shapes.
3. Remove a sector.
4. Obtain spherical segments or rings for rims or flanges.

Welding—Material can be added to modify head shapes by welding. Examples are:

1. Forming a gear cover by welding halves of a head to a plate.
2. Forming a pedestal by welding a head to a piece of tubing.
3. Forming a bracket by welding a bearing mount to a head shape.

The combination of cutting and welding offers designers considerable flexibility in adapting head shapes to varied applications. Some of these developments are reflected in the applications listed in the box above.

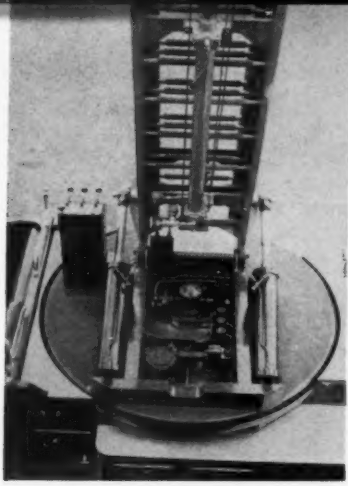
Sizes and tolerances

Heads have been produced from plate ranging from 3/8 to 7½ in. thick and in diameters ranging from 4 in. to 20½ ft.

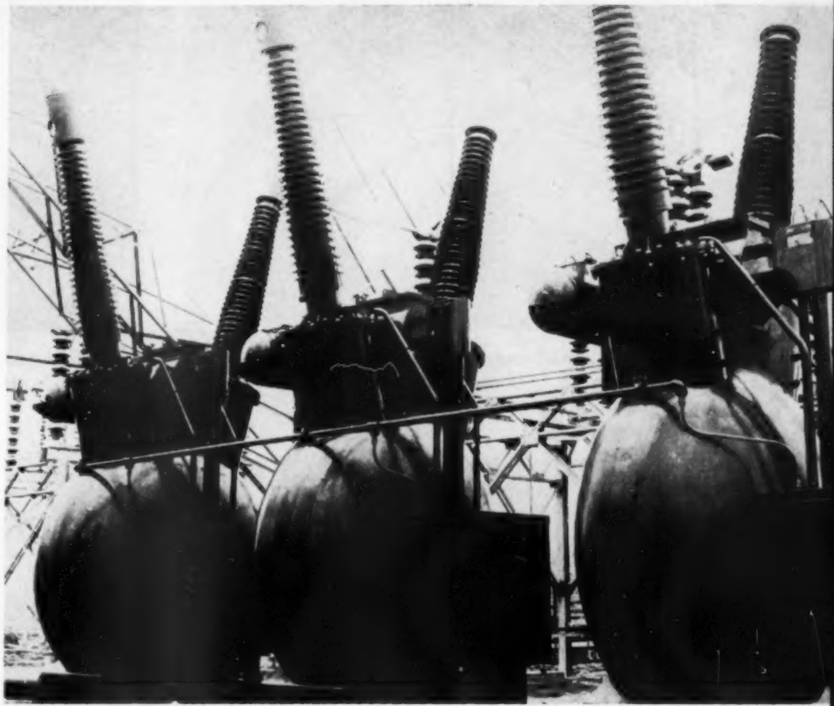
Closer tolerances can be held on pressed heads than on spun heads. Pressed heads are normally produced to an out-of-round tolerance of ¼ in. on the diameter. Spun heads are generally produced with an out-of-round tolerance of 1% of the diameter, although a maximum of ½ in. is held on small heads.

Some Uses for Head Shapes

- Blast deflectors and valve plates for heavy check valves.
- Rolls, end pulleys and plates for conveying machinery.
- Rims or shrouds for centrifugal fan wheels.
- Cylindrical heads in hydraulic elevators.
- Sealing rings for round hatches.
- River marking buoys.
- Radar antenna parts and turret bodies for radar pedestals.
- Covers or housings for circular machine components, such as gears.
- Bases, pedestals, frames and other circular structural members.
- Fan shrouds for locomotives.
- Disks in large vacuum valves.
- Dust covers in clay working machinery.
- Bellmouths for jet engine noise suppressors.
- Heads for pontoons.
- Covers for industrial floor polishers and vacuum cleaners.



Turnable base *for motor-driven aerial ladder is built from carbon steel, flanged head shapes.*



Circuit breakers *are built with elliptical head shapes. For other uses of head shapes,* *see p. 78.*

Materials

Heads are produced from a wide variety of materials. These include the entire range of carbon steel plates; alloy steels such as chromium - molybdenum, carbon-molybdenum and manganese-molybdenum; the standard stainless steels; and such high strength steels as T-1, H-11 and Tricent. Heads have also been produced from aluminum alloys, copper and copper alloys, nickel and nickel alloys, and titanium.

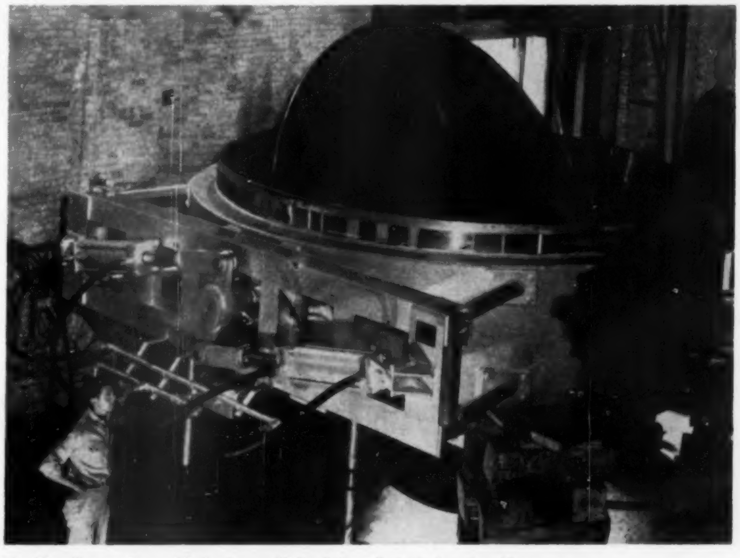
Clad steels are widely used. Heads are produced from carbon steel clad with stainless steels, monel, Inconel, copper and silver.

The properties of the alloys after forming into heads are the same as those of the plate from which the head has been formed. Spinning or pressing does not alter these properties. Properties of some of the materials that have been used in the production of heads are given in the table.

Pressed vs spun heads

Head shapes are made either by spinning or by pressing, the choice of the method depending on such factors as quantities and size.

Pressed heads — For pressed heads, it is necessary to have presses of adequate capacity and dies of the desired shape and dimensions. The cost of a set of dies is justified only when there is a big demand for the size. Pressing permits higher production rates than spinning.



Butterfly valve disk *is a dished head 168 in. in dia.*

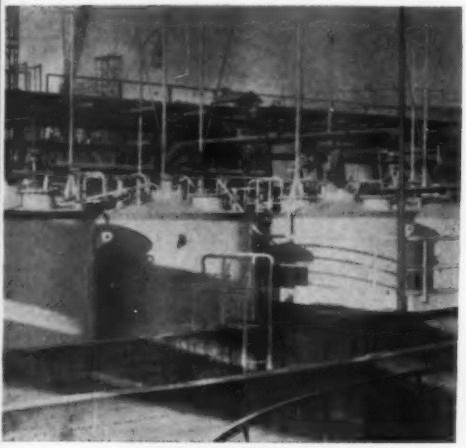
Spun heads—Spinning is more versatile than pressing; spun heads can be produced in any fractional increment of diameter for which production equipment is available, usually without additional die cost. Spinning is used for production of limited quantities of small heads or for head shapes that are too large to form on the pressing equipment that is available.

Tube Kote, Inc.

Steel and aluminum pipe *coated with baking-type urethane coating withstand postforming operations and resist acids, alkalis and solvents.*

Poly-Form Mfg. Co.

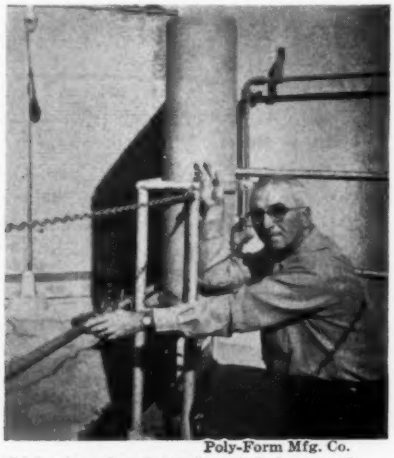
Pleasure boat *coated with urethane system is guaranteed against deterioration for two years.*



Storage tanks *for organic solvents are sprinkled with water to keep them cool in summer. Urethane coatings have provided good protection for four years and reduced maintenance costs.*

Poly-Form Mfg. Co.

Floor plate gratings *after six months exposure to highly corrosive sulfuric acid atmosphere. Corroded grating on left was coated with asphalt paint; undamaged grating on right has urethane coating.*



Poly-Form Mfg. Co.

Chlorine feed tank *(right) coated with urethane system resists weathering, salt air and industrial gases. Under same conditions, ordinary coating on horizontal feed pipe failed after short time.*

Tough, Chemical Resistant Urethane Coatings

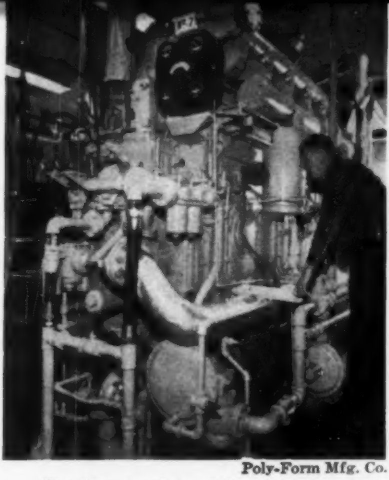
- *High resistance to water, chemicals, solvents and weathering*
- *High resistance to wear and shock*
- *High dielectric properties*

by R. S. Sansone, *Product Development Dept., Mobay Chemical Co.*

■ Urethane coatings have been successfully used for many years in Europe for a variety of protective applications. Their use in this country is comparatively recent; however, within a short time they have demonstrated a unique combination of mechanical and physical properties and resistance to a wide range of corrosive media. Here are the major types of urethane coatings, their properties and their uses.

Chemical and corrosion resistant coatings

Types—Chemical and corrosion resistant urethane coatings now available can be divided into three basic types: TDI-adducts, prepo-



Poly-Form Mfg. Co.

Engine *used to drive sewage pump is protected with urethane coating which resists heat, corrosives, fuels and lubricants.*

Water gas generator *is protected against corrosive fumes by urethane coating able to withstand temperatures from freezing to 250 °F.*

lymers, and baking types (for chemistry, see box at right). Also in this category are the newly announced polyurea coatings which are based on the reaction of urethanes with amine-bearing resins.

1. TDI-adducts — The most corrosion resistant air-dry urethane coatings are based on a TDI-adduct-polyester resin system (see box). These coatings are supplied in two-package systems made up of a resin package and an isocyanate package as follows:

Resin pkg	Isocyanate pkg
Resin	Isocyanate adduct
Pigment	Solvents
Additives	
Solvents	

What Are Urethane Coatings?

Three basic systems

The key ingredient in formulating urethane coatings is the versatile chemical, tolylene diisocyanate (TDI). This chemical has come to be known as a "toxic" material. However, provided that proper ventilation is used, it is actually safer to handle than many chemicals and solvents used in making plastics. In addition, special isocyanate-based chemicals have now been developed which make urethane coatings completely safe to use. These chemicals are the basis of three important urethane coating systems.

Adducts—In the most prominent system, TDI is reacted with polyols (alcohols containing many hydroxyl [OH] radicals) to produce adducts (the chemical name for addition products) that are much safer to handle than the TDI material itself. Some adducts still have enough TDI concentration to cause mild irritation. Recently, however, methods have been perfected that produce highly refined adducts which are completely safe to handle. These adducts are now being used in place of unmodified TDI to react with hydroxyl bearing resins to make durable urethane coatings. Such hydroxyl resins are those that have an "active" hydrogen, that is a hydrogen that can be displaced by sodium.

Prepolymers—Another way of making a more easily handled urethane coating is to pre-react TDI with hydroxyl-bearing resins to produce long chain polymers. These pre-reacted polymers are called prepolymers and, at the time of application, react further in the presence of moisture or catalysts to form tough films.

Blocked adducts—Because of the highly reactive nature of adducts and prepolymers they have to be kept separate from the resins or catalysts until just prior to use. This difficulty can be overcome by making adducts that are chemically "blocked," or nonreactive at ambient temperatures. Thus, the blocked adducts can be blended with resins and catalysts into one package without any reaction taking place. Reaction occurs only when the coating is baked. High temperatures then release the blocking agent and allow the adduct to react with the resins and form the final coating.

Resins that can be used

Materials that contain hydroxyl or amine groups, such as alcohols, polyols, amines, polyamines, polyesters, epoxies and phenolics, are but a few of the hydrogen-bearing compounds capable of reacting with TDI to form long chain molecules. However, the basic resins currently being used with the three urethane coating systems discussed above are saturated polyester resins, polyether resins and castor oils.

End properties of the coating depend on both the type of resin and the proportion of isocyanate used. The resin determines such properties as flexibility, hardness, and resistance to impact and abrasion. In general, increasing the proportion of isocyanate to resin will produce increased coating durability. At present the two coating systems that appear to have the greatest potential for industrial applications are 1) the two-package air drying coatings using a TDI-adduct with polyester resins or castor oils, and 2) the prepolymer coating system with catalyst.

Other coating systems

Because of their versatility and ability to react with active hydrogen-containing compounds, technologists expect that polyisocyanates can be used to produce completely new and different urethane coatings with properties not obtainable in any other coating system. Polyisocyanates have already been used to upgrade the properties of linseed and other natural oils, coal tar enamels, and alkyd, epoxy and phenolic coatings. They are also being used to modify silicones to improve adhesion and lower costs.

Just prior to application the isocyanate package is added to the resin package and mixed thoroughly. Pot life of the mixture is usually 8 to 24 hr, which allows for handling of convenient quantities on a job site. Ordinarily, the coatings have a combination of low viscosity and high solids content which allows them to be easily applied in heavy thicknesses. However, suitable viscosity improvers can be incorporated if lower solids content is desired.

2. Prepolymers—Two-package prepolymers (see box) are also available for protection against chemicals and corrosion. These prepolymers are made up as follows:

Prepolymer pkg	Catalyst pkg
Prepolymer	Catalyst
Solvents	Solvents
Additives	

Because of their reactive nature, prepolymers are difficult to pigment and thus are available only as clear coatings. In order to provide adequate stability in the can, prepolymers are usually made up with linear-type resins. Such resins do not provide very good resistance to chemicals, but they are quite resistant to water, weathering and wear.

3. Baking types—As in the case with most coatings, the properties of urethane coatings can be improved by baking. Special baking-type urethane coatings based on a blocked-type isocyanate adduct (see box) have higher chemical resistance and durability than all other types of urethane coatings.

4. New polyurea coatings—Recent announcement has been made of a new class of solvent or water emulsion coatings based on the reaction of diurethanes (tolylene diisocyanate reacted with aliphatic alcohol) with amine-bearing resins. These coatings (especially the one-package water emulsion coatings) are expected to be especially useful as industrial primers or as one-coat protective coatings.

Except for the lower gloss of pigmented water emulsion coatings, there is little difference between the properties of solvent and water emulsion polyurea systems. Coatings are available that successfully resist immersion in 10% hydrochloric or acetic acids, or 20% sulfuric or nitric acids. Coatings have been immersed for 300 hr in caustic solutions with-

TABLE 1—PROPERTIES OF URETHANE COATINGS[a]

Type ➜	Chemical Resistant	Baking	Flexible[b]	Flexible Prepolymer
APPEARANCE				
Color	Exc	Good	Exc	Exc
Color Retention	Good	Good	Good	Good
Initial Gloss	Exc+	Good	Exc+	Exc+
Gloss Retention[c]	Poor[d]	Poor[d]	Poor[d]	Poor[d]
MECHANICAL PROPERTIES				
Hardness	Exc+	Exc+	Exc+	Exc+
Adhesion	Exc	Exc	Exc	Exc
Flexibility and Impact Resistance	Exc	Exc	Exc	Exc
Abrasion Resistance	Exc+	Exc+	Exc+	Exc
CHEMICAL RESISTANCE				
Cold Water	Exc+	Exc	Exc	Exc
Hot Water	Fair	Fair	Fair	Fair
Solvents				
Aliphatics, Aromatics	Exc	Exc	Exc	Exc
Alcohols, Ketones, Esters	Fair-good	Good	Fair-good	Fair-good
Alkalis	Good	Good	Good	Fair-good
Acids				
Dilute	Fair-good	Fair-good	Fair-good	Fair-good
Concentrated	Poor	Poor	Poor	Poor
ENVIRONMENTAL PROPERTIES				
Heat Resistance	Exc	Exc	Exc	Exc
Exterior Durability[e]	Exc[f]	Exc[f]	Exc[f]	Exc[g]
APPLICATION				
Methods	Unlimited	Unlimited	Unlimited	Unlimited
Approximate Solids at Spray Viscosity, %				
Clear	40	40	40	35
Pigmented (white)[h]	50	50	50	—
Thickness (sprayed), mils	1-2	1-2	1-2	1-2
Cure[i]	A or B	B	A or B	A or B
Bake Schedule	10 min @ 250 F	30 min @ 300-350 F	10 min @ 250 F	15 min @ 260 F

[a]Exc+ = generally superior to other organic coatings; Exc = excellent but not the optimum obtainable with other urethanes or other organic coatings.
[b]Two-component system using isocyanate-adducts and linear-type polyester or polyether resins.
[c]After exterior exposure.
[d]Loss of gloss due to chalking; does not affect other coating properties.
[e]Other than gloss retention. [f]Clear and pigmented. [g]Clear only.
[h]Titanium dioxide. [i]A = can be air dried; B = can be baked.

TABLE 2—WHERE URETHANE COATINGS ARE USED

Chemical Resistant Type	Machinery, swimming pools, drums, tanks, floors, structural steel, laboratory and hospital furniture. Various chemical and petroleum equipment. Marine and industrial maintenance coatings
Baking Type	Cans, drums, pipe, tanks, impregnating varnishes, self-solderable wire, coatings. Coatings for brass, copper, aluminum and glass surfaces
Flexible Type	Molded rubber goods, toys, textiles, plastics, glass cloth, leather, conveyor belts, masonry
Flexible Prepolymer Type	Molded rubber goods, toys, furniture, cloth, paper, leather, floors, marine parts. Interior and exterior finishes for wood and masonry

out damage. Excellent resistance to water, aliphatic hydrocarbons and hexane is also obtainable. However, the coatings soften in contact with butanol, methyl ethyl ketone, and toluol.

Properties—The best of the corrosion resistant urethane coatings provide excellent resistance to moisture, water immersion, chemicals, solvents, hydraulic fluids and weathering. In combination with these properties, the coatings can also be provided with high hardness and good impact properties which make them highly resistant to wear, chipping and mechanical abuse. All of these properties are generally obtainable in an air-dry urethane coating based on a TDI-adduct-type isocyanate. The chemical resistance and durability of these coatings is claimed to be higher than that of any other type of air-dry coating.

Urethane coatings are not presently practical where a high degree of whiteness retention is required. The coatings tend to yellow in white and pastel shades on exposure to ultraviolet light and are thus unsuitable for light appliance colors. Such yellowing, however, does not affect the corrosion resistance or durability of the coatings. Urethane coatings are comparable in color and gloss retention to other corrosion resistant coatings, and are considerably better than conventional oil-type varnishes.

Applications—The unique combination of properties of urethane coatings has been utilized in a variety of applications. Air-dry coatings are now successfully being used in swimming pools, on concrete and wood floors, fuel tanks and barges, interior and exterior water storage tanks, pipe lines, garages, bowling alleys, laboratory furniture, machinery, ventilation equipment and marine equipment. A number of protective and decorative coatings are also available for wood finishing. The natural beauty of wood is greatly enhanced by clear urethane varnishes which have a deep, rich luster.

A noteworthy application of the special blocked adduct baking coatings is their use on magnet wire and other uncovered electrical wire. In addition to their high durability these coatings have excellent dielectric properties and are unique in that they have a self-fluxing action, i.e., they do not need to be removed prior to soldering the wire. Because of these properties, the coatings are becoming increasingly popular for coating fiberglass cable coverings.

The baking-type urethane coatings are also being successfully applied to oil well drilling pipe where their high chemical and oil resistance and resistance to shock provides a versatile and tough coating system.

Flexible coatings

Urethane coatings with a high degree of flexibility can be formulated from either: 1) a two-package system using isocyanate-adducts and linear-type polyester or polyether resins, or 2) prepolymers with catalysts. The isocyanate-adduct-resin systems are available as pigmented or clear coatings, whereas the prepolymers are available only as clear coatings. In some applications, it is convenient to apply a clear prepolymer topcoat over a pigmented isocyanate-adduct-resin base coat.

The degree of flexibility obtainable with urethane coatings depends on the resin used and the ratio of resin to isocyanate. Normally, a linear polyester or polyether resin with an isocyanate adduct will produce coatings of sufficient flexibility to be used on such substrates as paper, leather, glass cloth, textiles and rubber.

Although they show some loss in chemical and solvent resistance, air drying flexible urethane coatings provide outstanding resistance to weathering and wear. These coatings are being successfully used on such flexible substrates as tarpaulins, leather and rubber footwear, automobile weatherstripping, conveyor belts and sporting equipment.

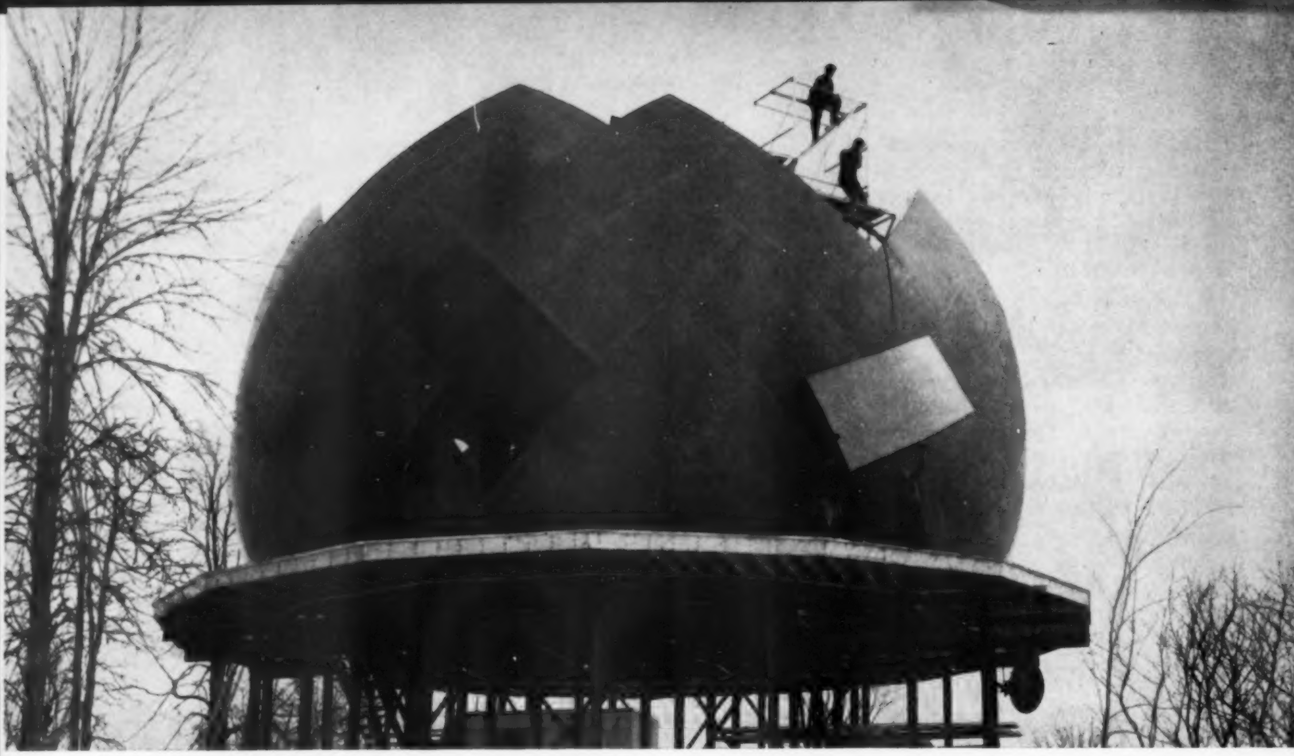
Primers for urethanes

For most exposure conditions, a baked urethane coating does not require a primer. Even air-drying urethane coatings have excellent adhesion to clean, dry metal surfaces. However, air drying coatings must be applied over a primer in immersion service and highly corrosive atmospheres.

Swimming pool *needs less maintenance when protected against water and weather with urethane coating.*

Conventional polyvinyl butyral wash primers are good for aqueous immersion or industrial atmospheres. Epoxy-amine primers are recommended where exposure to chemicals and solvents is likely. Another excellent primer is a one-package urethane-modified epoxy system which has excellent water and chemical resistance when used with urethane topcoats.

When urethane coatings are to be applied to wood surfaces, it is important to consider what type of pretreatment will provide the best results. Coarse-grained wood, such as redwood and southern yellow pine, should be filled to prevent excessive soaking of the coating. Commercial oil or water-base wood fillers for open-grain woods are not recommended with urethane coatings because they do not promote adhesion. However, a wood filler based on castor oil has been developed for urethanes which has excellent adhesion and is easily applied, non-drying and inexpensive. This filler soaks into the wood and promotes adhesion by reacting with the isocyanate in the coating.



***Quick-release fasteners** were used to assemble this radome. They were bonded to both skin and core of glass-reinforced plastics laminates during fabrication.*

How to Use Mechanical Fasteners with Reinforced Plastics

Many standard fasteners developed for other materials can be used with glass-reinforced plastics. This article tells how to select and design for bolts, screws, inserts and rivets.

by Marshall D. Weiss, *Owens-Corning Fiberglas Corp.*

■ Although many assembly problems involving glass-reinforced plastics are solved by adhesive bonding, there are cases where mechanical fastening is necessary. Such cases include access doors, covers, parts requiring replacement or removal for repair, joints subjected to complex loading, and joints involving materials of different thermal expansions.

The principal fasteners used are bolts, rivets and screws. Consideration must always be given to the fact that the low ductility of the plastics will cause local stress concentration and result in unequal load distribution. The lower values of shear and bearing strengths also require that plastics be treated with more care than metals.

Bolts

In specifying a bolt-and-nut fastening for a particular joint design, consideration must be given not only to the expected service loads but also to the assembly stresses set up in the fastener. Excessive torque at assembly, particularly with small bolts, can cause damage to the plastics surfaces under the head or nut. This is true even though the axial load developed from the torque may only be 10% of the total. When the total load is considered it may be necessary to provide washers or bolting strips against the plastics surfaces. In severe cases metal spacers (see Fig 1) may be used.

Bolt size—A minimum ratio of bolt dia to laminate thickness (d/t) of 1 allows the plastic to develop full bearing strength. If d/t = ½ it is possible to shear the bolt before the plastic fails.

Hole size—Holes should be well aligned and drilled or reamed 1/64 in. larger than bolt dia. Misalignment results in large stresses when the fastener is inserted.

Spacing—At small edge distances, failure usually occurs through shear-out at the ends, or through tensile failure of the outer section. It is not correct to base the load-carrying capacity of the outer section on the section area and tensile strength of the plastic. The effect of notch sensitivity must also be taken into account. This is done by multiplying the average stress by 3½. Design tables will then indicate that an edge distance of 4.5 times the bolt diameter (d) and a side distance of 3.5 d should be the minimum. Side distance is measured along the line of bolt centers; edge distance perpendicular to the centerline.

Rivets

Rivets are used particularly when joining plastics to a metal, with the rivet head on the plastic side. If at all possible, riveted joints should be designed so the rivets are not in tension. If tensile loading is unavoidable, the tensile strength of a rivet may be taken as one-half the standard safe shear values for the particular rivet diameter.

Rivet — Diameter should be equal to or greater than plastic thickness. The rivet point should protrude beyond the metal a distance equal to or greater than the rivet diameter.

Hole size—Rivet holes need to be large enough for rapid and easy assembly but not so large as to allow bulging or buckling with consequent eccentric upsetting. A hole 1/64 in. larger than the rivet dia is generally adequate.

Spacing—Spacing between rivets is determined from standard rivet shear strength tables by applying a safety factor of 3 to 4 to allow for the bearing strength of the plastic. As for bolts, the minimum recommended edge distance is 4.5 d and side distance is 3.5 d.

Setting—The recommended rivet gun is a pneumatic hammer delivering 1700 strokes per min at 90 psi. The rivet set shape should correspond to the manufactured head. The bucking bar should be a 1 or 1½-in. dia steel rod about 15 in. long.

Special rivets — Pull-through blind rivets have a pin which, after the rivet is driven, is pulled back through to expand the rivet to fill the hole. Aside from the obvious advantage of allowing the use of rivets where there is no access to one side, pull-through rivets are rapidly installed and less likely to cause damage to the plastics surface.

Drive rivets are installed with a hammer by driving a steel groove pin into a cored aluminum rivet. Metal at the rivet head, originally displaced by grooved projections, flows back around the pin for added locking action. This type of rivet is also available in a variety of plastics materials: nylon, acetate, butyrate, polystyrene and polyethylene.

Screws

Many joint designs are best satisfied by a fastener threaded into the plastic. Three basic types of screws are used—machine, thread forming and thread cutting. Fig 2 indicates the pull-out strength of average size screws of each type. Table 1 gives the holding force of machine screws in various types of glass reinforced plastics.

Thread forming screws, supplied as standard in case hardened steel and also available in several types of 18-8 stainless steel, often resist vibration, tension and shear stresses better than machine screws. Thread cutting screws are made in coarse and fine threads. The two types have about the same driving and stripping torques, but the fine thread type has less tendency to delaminate the entering surface of the plastic.

Pilot hole size—With a particular fastener and particular glass-reinforced plastic, pull-out strength varies directly with fastener diameter. As Table 2 indicates, for low glass-content mat laminates there is an optimum pilot hole size for maximum pull-out strength. For the cloth laminate and 37% glass mat laminate, the pull-out strengths are higher with smaller pilot hole sizes. That this is not true for the low glass mat is probably due to stresses induced in the plastic in driving the fastener.

Design factors—Table 3 enables the calculation of total strength of typical thread cutting and thread forming screws. The strength is based on a strength for initial penetration plus strength per each 1/16-in. additional penetration.

Other screws — Self-drilling screws have recently been developed and should result in high cost savings. They are similar to the thread cutting type with the addition of an off-center cutting edge and a gimlet point. Their strength is expected to be slightly lower than that of the two self-tapping types.

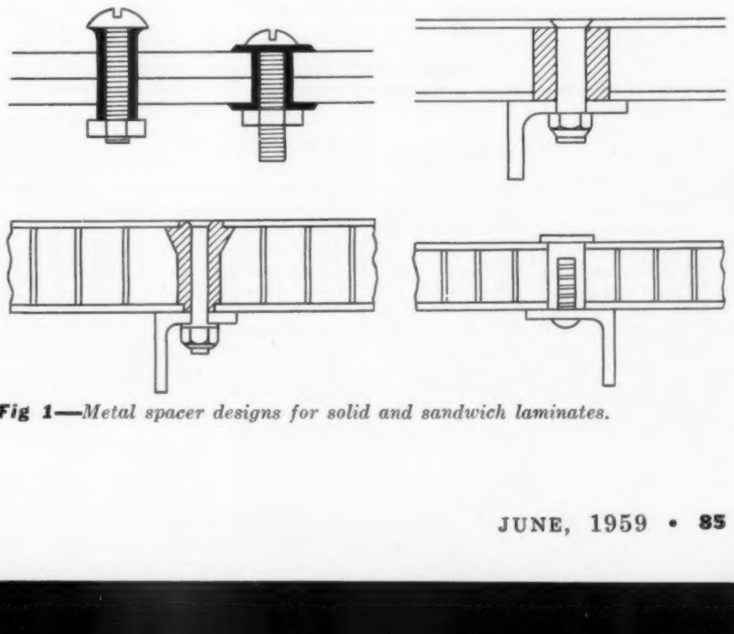


Fig 1—*Metal spacer designs for solid and sandwich laminates.*

Pull-Out Strengths for Screws

TABLE 1—HOLDING FORCES OF MACHINE SCREWS IN GLASS-REINFORCED POLYESTER

Screw Size	Material Type[a]	Penetration Depth, 1/16 in.[b]	Axial Force, lb	Penetration Depth, 1/16 in.[b]	Lateral Force, lb
4–40	181C	2–5	130–500	1–2	210–350
	1000C	1–3	90–500	1–2	180–350
	Mat	2–5	40–450	1–2	150–290
6–32	181C	2–6	170–820	1–3	250–700
	1000C	1–4	110–700	1–2	220–450
	Mat	2–6	60–600	1–2	180–380
8–32	181C	3–7	320–1140	2–3	440–810
	1000C	2–5	230–1000	1–3	280–880
	Mat	2–7	100–1150	1–3	220–750
10–32	181C	3–8	420–1500	2–4	850–1200
	1000C	2–6	260–1500	2–3	750–1100
	Mat	2–8	150–1500	2–4	560–1350
1/4–20	181C	4–10	700–2800	2–5	1200–1900
	1000C	2–8	320–2700	2–4	1000–1800
	Mat	3–10	300–2300	3–5	1300–1900
5/16–18	181C	4–12	820–4200	3–6	2100–2800
	1000C	3–10	520–4000	2–6	1350–2000
	Mat	3–12	400–3600	3–7	1600–2900
3/8–16	181C	5–14	1160–6000	4–7	3300–3900
	1000C	3–11	620–4850	3–7	2600–3300
	Mat	4–14	530–5000	4–10	2600–4000
7/16–14	181C	5–15	1300–8000	4–8	3800–5200
	1000C	4–13	950–6800	3–9	3000–4500
	Mat	4–16	580–6500	5–12	3800–5000
1/2–13	181C	6–17	1660–9800	5–10	5300–7500
	1000C	4–15	1100–7720	4–10	4500–6000
	Mat	4–18	620–8300	6–14	5500–6000
9/16–12	181C	6–18	1820–12,000	5–11	5800–9000
	1000C	5–16	1600–9,000	5–12	6000–9000
	Mat	4–20	650–10,000	7–15	6500–8000
5/8–11	181C	7–20	2200–15,300	6–13	7300–11,900
	1000C	5–18	1750–11,600	5–13	6500–10,000
	Mat	4–22	680–12,000	7–16	6800–11,000
3/4–10	181C	7–22	2550–20,600	7–15	8900–15,000
	1000C	6–22	2500–24,000	6–16	8000–15,000
	Mat	4–24	700–13,500	7–17	7000–17,000

[a]Code: C = cloth; mat is 1 1/2 oz.
[b]Minimum and maximum values yielding corresponding axial and lateral forces as indicated.

TABLE 2—EFFECT OF PILOT-HOLE SIZE ON PULL-OUT STRENGTH OF SELF-TAPPING SCREWS

Material	Drill	Dia	Strength, lb[a]
1000 Cloth (56% glass)	3	0.2130	3110, 2830
	2	0.2210	2870, 2690
	1	0.2280	2800, 2290
	15/64	0.2343	2080, 1815
	C	0.2420	1430, 580
Mat (37% glass)	3	0.2130	2690, 1510
	2	0.2210	2600, 1620
	1	0.2280	2670, 1190
	15/64	0.2343	2400, 1040
	C	0.2420	1870, 500
Mat (15% glass)	3	0.2130	1640, 1150
	2	0.2210	1750, 1510
	1	0.2280	1850, 1400
	15/64	0.2343	1670, 1130
	C	0.2420	1370, 380

[a]First value is for type F, 1/4-20, thread cutting screw; second value is for Z, 14/14, thread forming screw. Penetration depth in both cases is 3/4 in.

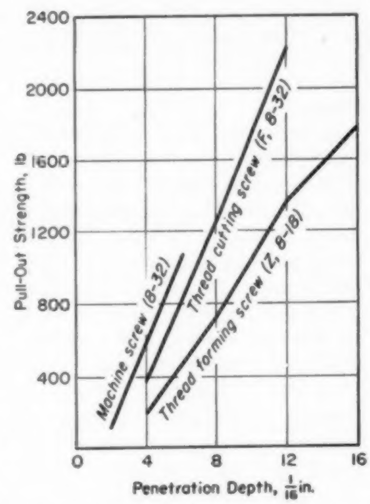


Fig 2—Pull-out strengths of typical screws used to fasten mat laminate (37% glass, 1½ oz mat, polyester resin).

TABLE 3—PULL-OUT STRENGTH OF TYPE F THREAD CUTTING SCREWS

Type, Size[a]	Breaking Load, lb	Initial Penetration, 1/16 in.	1 1/2-Oz Mat (37% glass)		1000 Cloth (66.5% glass)	
			Strength, lb[b]	Range of Validity, 1/16 in.[c]	Strength, lb[b]	Range of Validity, 1/16 in.[c]
F, 4–40	650	2	10, 150	2–6	70, 130	2–6
F, 6–32	1300	4	130, 90	4–12	250, 185	4–9
F, 8–32	2200	4	360, 230	4–12	400, 195	4–12
F, 1/4–20	4000	5	400, 300	5–17	350, 365	5–12
Z, 4–24	650	2	70, 150	2–6	110, 115	4–6
Z, 6–20	1100	4	200, 165	4–9	110, 85	4–10
Z, 8–18	2000	4	120, 170	4–15	180, 145	4–14
Z, 14–14	4300	5	300, 300	5–18	100, 265	5–20
Z, 3/8–12		4	100, 410	2–16	200, 250	4–8

[a]Code: F = type F thread forming screw; Z = type Z thread cutting screw.
[b]First value is strength at initial penetration depth; second value is the additional strength for each additional 1/16 in. of penetration.
[c]Range of penetration over which second figure in strength column can be applied.

Inserts

Among the advantages of internally threaded inserts as compared with self-tapping screws are:

1. The o.d. of the insert is much larger than the fastener itself and affords increased bearing area.

2. The larger shear area in contact with the plastic provides greater pull-out strength.

3. The insert material is harder than the plastic and better able to take the wear out of repeated removal and replacement.

4. Some designs provide locking features which prevent vibration loosening of the screw.

Types—Inserts may be molded in place or installed after molding. Molded-in-place inserts find better application in those parts made with premix molding compounds. When used with mat or preforms, adequate reinforcement immediately adjacent to the insert becomes a problem.

Inserts installed after molding can be classified as one of three types:

1. Self-tapping. These have external threads with a cutting slot for forming mating threads in untapped holes. Once installed, the insert is firmly locked to the laminate. They are generally supplied in case hardened steel for glass-reinforced plastics in sizes from No. 4 to ¾ in.

2. Self-threading. One of the more popular forms of this type consists of a precision formed coil of diamond-shaped wire. When seated in a specially tapped hole it provides threads that resist wear and withstand higher loads than conventional tapped threads. The threads are flexible and permit shrinkage of the plastic without cracking of the insert. The inserts are available in stainless steels, sometimes other metals, in sizes ranging from No. 4 through 1½ in.

Other types of self-threading inserts are machined from solid steel stock. They are generally threaded into a tapped hole with a screwdriver or inserting tool. Some are provided with locking pins or collars to prevent the insert from turning during installation or removal of the screw.

3. Push-in inserts. These are simply pressed into drilled holes. They are held in place by knurls, fins or annular rings on their outer surfaces, expanding as the screw is inserted. The pull-out strength is governed by the size of the hole and is lower than for the other types.

Other fasteners

In addition to a number of highly specialized fasteners, two types of importance are staples and quick-release fasteners.

Staples—The use of staples provides a high speed method of fastening parts which have suitable flanges. The majority of applications to date are those which require a fastening to supplement an adhesive bond while curing.

Quick-release types—Developed mainly for the aircraft industry, this fastener is most valuable in applications requiring frequent assembly or removal of covers, doors, etc. Some types have a desirable thermoplastic flange which bears against the surface of the glass-reinforced plastics and prevents damage through vibration stresses.

Pre-fastener operations

Drilling—Drill speeds of 65 to 80 sfpm and a feed of 0.016 in. per rev are recommended for a ½-in. drill. The following points should help to achieve best results.

1. Drilling operations parallel to the laminations should be avoided.

2. Drills must be kept sharpened.

3. Drills specially designed for glass-reinforced plastics are best and should be 0.002 to 0.004 in. oversize.

4. Some drill manufacturers recommend an included angle at the drill tip ranging from 55-60 deg for thin sections to 90-100 deg for thick sections.

5. A piece of plastic, wood or metal should be clamped to the bottom surface of the plastic to prevent "breaking out."

6. During drilling, the drill should be backed from the hole frequently to remove chips and allow cooling.

7. Coolants are advisable because glass-reinforced plastics are poor conductors of heat.

8. Glass dust should be removed with an exhaust system.

Punching—Punching holes requires about half the press capacity used for steel. The following practices should be carefully observed:

1. Punch diameter should be oversize by 4 to 5% of the section thickness.

2. A stripping plate of high spring tension is necessary to strip the part from the punch.

3. Die clearances should be half those specified for steel.

4. Dies should be made of Carpenter No. 610, or equivalent, and hardened to Rc 60.

5. The minimum punched hole diameter should be ¾ of the section thickness.

6. Sharp edges are obtainable in sections up to 3/32 in. The quality in thicker sections up to 5/32 in. is fair. Beyond, up to ¼ in., the holes are rough but clean.

Tapping—The maximum accuracy is a Class 2 fit with a 75% thread. Inserts are used if a more precise fit is required. These rules should be followed:

1. Tap drill holes should be smoother and slightly larger than for metals.

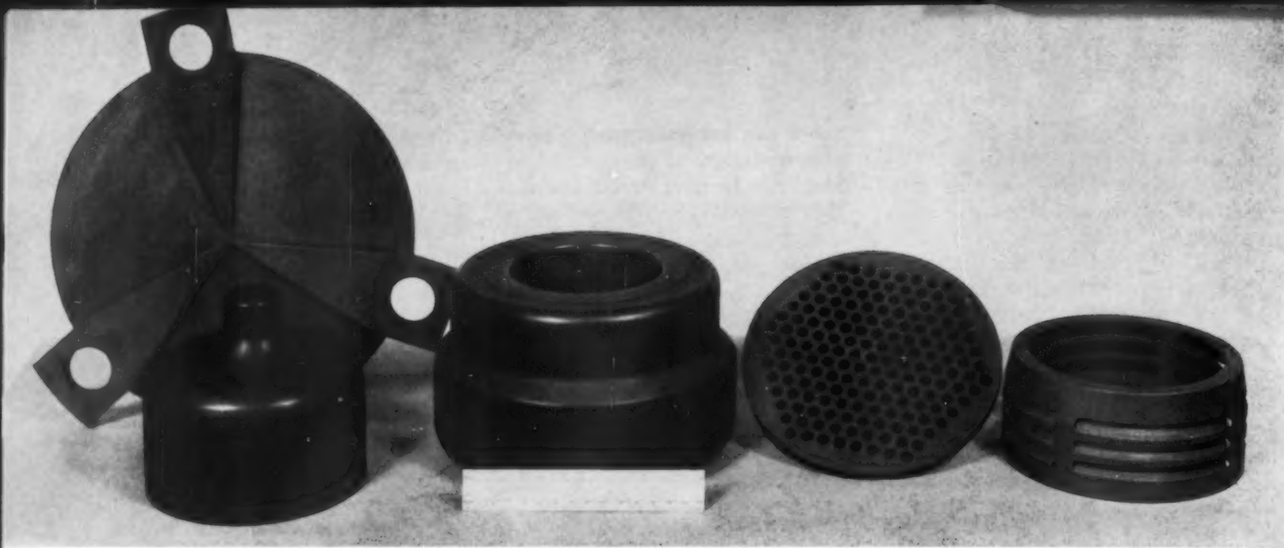
2. In blind holes the tap drill should enter far enough to provide a minimum clearance of three threads.

3. Before tapping, the edge of the hole should be chamfered slightly with a countersink.

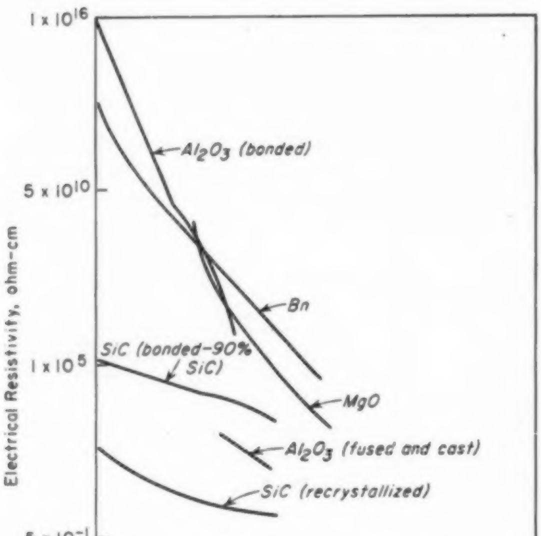
4. Taps should be made of chromium-plated and ground high speed steel and should have two or three flutes. Gun taps are best for through holes.

5. Taps should be 0.002 to 0.008 in. oversize, preferably with a negative rake of up to 10 deg, depending on size and pitch and on type of material.

6. False cutting should be avoided.



Anodes, grids and baffles *make use of graphite's high temperature strength, refractoriness, electrical conductivity and dimensional stability.*



Electrical resistivity

The materials compared in the curves range from electrical conductors to insulators. Graphite is a very good electrical conductor, with a low resistivity essentially unaffected by temperature. Graphite's electrical properties can be altered substantially by control of raw materials and fabrication methods. Graphite is lower in cost than most metal conductors.

Graphite—How It Compares with Metals, Ceramics

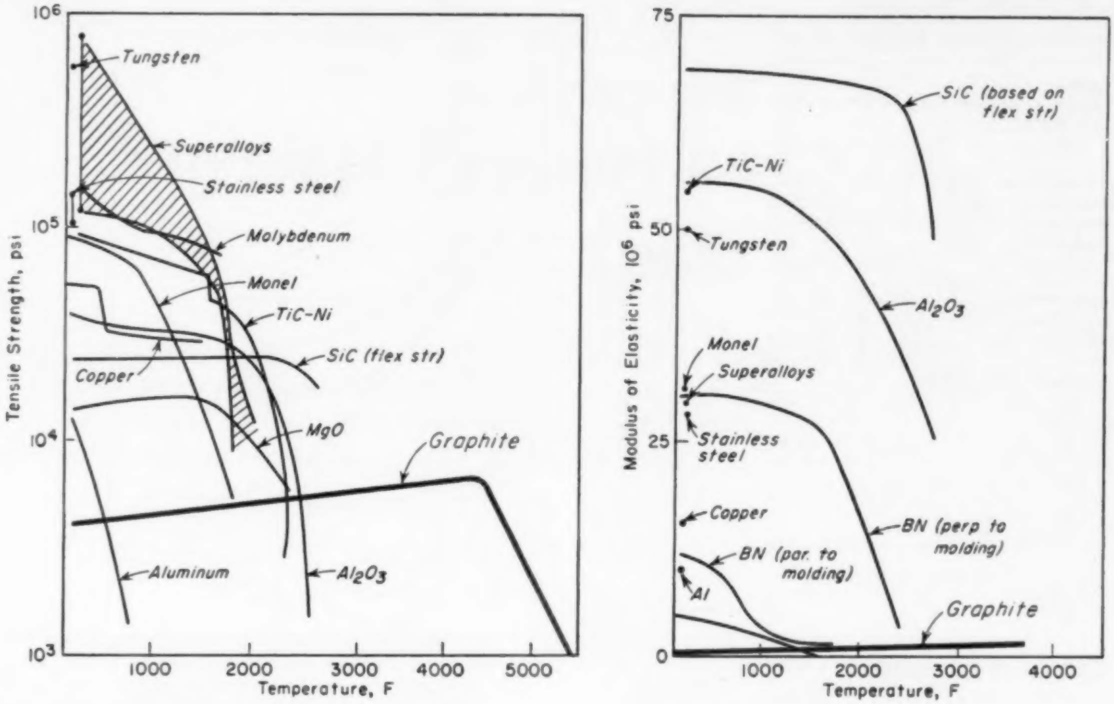
by G. B. Engle and L. M. Liggett, *Research Laboratory, Speer Carbon Co.*

The most common uses for graphite depend on its electrical conductivity, its high temperature strength and its good thermal characteristics (see box on p 90). These properties of graphite have been widely reported.

The purpose of this article is to compare these well-known properties of graphite with those of other engineering materials which are outstanding in electrical, mechanical or thermal properties. Materials for comparison were selected to cover the 32-5500 F temperature range. For example, such metals as aluminum and copper may be compared at the lower operating temperatures; certain alloys and refractory metals may be compared at intermediate operating temperatures; and cermets and ceramics may be compared at higher operating temperatures.

Property values for materials such as graphite, cermets and ceramics may vary widely, depending on processing variables or specific raw materials used. The property data in the following sections have been carefully selected from the literature as being representative of the various materials. In some cases a range of properties is given.

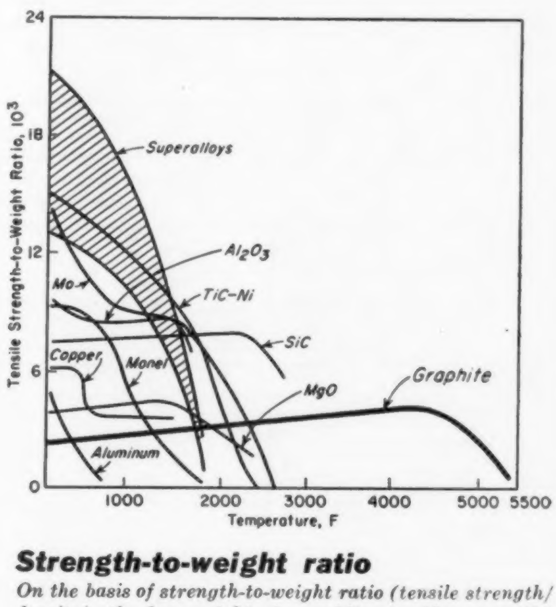
This article is adapted from a paper presented at the '58 Fall Meeting of the Electrochemical Society, held in Ottawa, Ont.



Tensile strength and modulus

The most important strength characteristic of graphite is that strength increases with increasing temperature up to about 4500 F. The curves show graphite's room temperature tensile strength (left) and modulus (right) to be much lower than in most other materials. However, above 2500 F, where strengths of other materials fall off rapidly, graphite's strength increases with temperature.

Exhaust vanes *and divergent cones for missiles make use of graphite's high temperature strength, refractoriness and dimensional stability.*



Strength-to-weight ratio

On the basis of strength-to-weight ratio (tensile strength/density), the low weight of graphite provides a smaller difference in strength between materials, than comparisons based on strength alone. Graphite's density is about 0.05-0.07 lb per cu in.

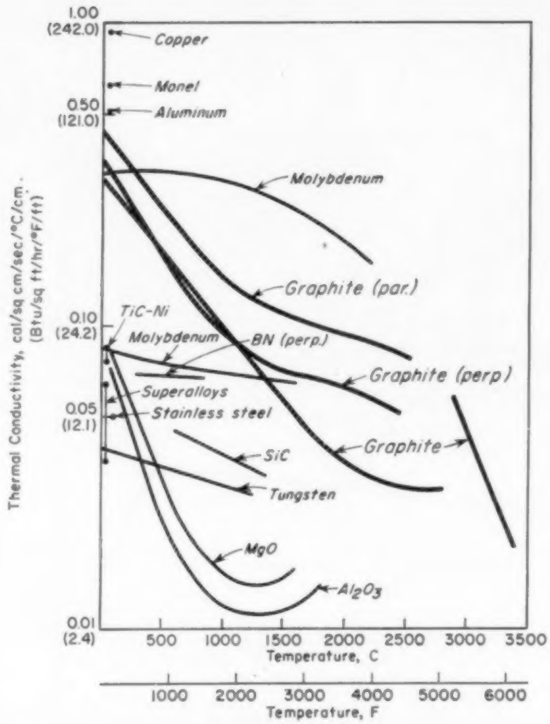
Coefficient of Thermal Expansion, per °F[a]

Graphite	
Parallel to Extrusion	$2.1\text{-}2.8 \times 10^{-6}$ (32-6300)
Perpendicular to Extrusion	3.5×10^{-6} (32-6300)
Aluminum Oxide (Al_2O_3)	4.4×10^{-6} (68-2900)
Magnesium Oxide (MgO)	7.8×10^{-6} (68-2500)
Silicon Carbide (SiC)	$2.4\text{-}2.5 \times 10^{-6}$ (68-3000)
Titanium Carbide-Nickel Cermet (TiC-Ni)[b]	4.5×10^{-6} (32-1200)
Aluminum (Al)	14.2×10^{-6} (68-575)
Copper (Cu)	9.2×10^{-6} (32-575)
Molybdenum (Mo)	4.0×10^{-6} (80-3600)
Monel[c]	5.6×10^{-6} (77-1100)
Stainless Steel Type 316 (SS)[d]	11.0×10^{-6} (32-1500)
Superalloy[e]	6.4×10^{-6} (32-1200)
Tungsten (W)	2.4×10^{-6} (near 68)

[a]Complete list of sources for data available from authors. Parenthetical values are temperature ranges in °F.
[b]10 TiC-30% Ni.
[c]67 Ni-30 Cu-1.4 Fe-1 Mn-0.15 C-0.1 Si-0.01% S.
[d]68.9 Fe-17 Cr-12 Ni-2.5 Mo-0.1% C.
[e]Representative values for Co-Cr-Ni and high Ni alloys.

Thermal expansion

Graphite's low coefficient of thermal expansion contributes to good thermal shock resistance and high temperature dimensional stability. As can be seen in the table, of the metals only tungsten and molybdenum have values in the same range as graphite. Of the nonmetallics, only silicon carbide has an expansion coefficient in the same range, and its use is limited to temperatures up to about 3400 F.



Thermal conductivity

Of the materials compared here, graphite's room temperature thermal conductivity is exceeded only by that of copper, monel and aluminum. At elevated temperatures, the only common metal with higher thermal conductivity is molybdenum. None of the high temperature alloys, cermets or ceramics, approaches graphite in thermal conductivity. Note that the conductivity of graphite is greater parallel to direction of extrusion than perpendicular to extrusion direction. The reason is that the crystals are mechanically aligned with their basal planes parallel to the extrusion direction.

Graphite and Its Uses

Commercial graphite is a polycrystalline, refractory material prepared by mixing a filler material, usually calcined petroleum coke, with a binder, usually coal-tar pitch. The mixture is formed to desired shape by molding or extruding, and baked in an inert atmosphere. It is then heated to 3500-5500 F to promote crystal growth.

Outstanding characteristics of graphite include its exceptional thermal properties, strength at high temperatures, refractoriness, good electrical conductivity and excellent nuclear properties.

The major limitation of graphite is its poor oxidation resistance. If current efforts directed at overcoming this difficulty are successful, many new high temperature uses will be opened to graphite.

The accompanying table shows the properties of graphite which adapt it to specific uses in various industries.

These properties → are responsible for these uses ↓	High Ther Cond	Excellent Ther Shock Res	Low Coef of Ther Exp	High Elec Cond	High Temp Str and Dimen Stability	Low Chem Activity
INDUSTRIAL						
Electrodes	X	X		X		
Anodes				X		X
Molds	X	X	X		X	
Crucibles		X	X		X	X
Structural Uses		X	X		X	X
NUCLEAR[a]						
Moderators	X	X	X			
Reflectors		X	X			
Fuel Element Jackets	X	X	X		X	X
ROCKET, MISSILE						
Vanes		X	X		X	
Motor Linings		X	X		X	X

[a]Other good nuclear properties include good radiation stability at moderate temperatures, good moderating properties and low thermal-neutron-absorption cross section.

Materials
in Design Engineering

Manual No. 159
June 1959

A glossary of

Physical Properties and Tests

Compiled by
John B. Campbell,
Managing Editor,
Materials in Design Engineering

of the common engineering materials. This compilation is designed to give engineers a brief, easily visualized idea of the meaning of each property in terms of the test by which it is determined. The major groups of properties covered:

- *Electrical*
- *Magnetic*
- *Thermal*
- *Density*
- *Optical*
- *Acoustic*

Acoustic Impedance, Specific Normal

An index to the proportion of incident of sound energy reflected by a material. Acoustic Impedance of a material (z) and its components are generally expressed as the ratio to the acoustic impedance of air (ρc). Acoustic Impedance, $z/\rho c$, can be calculated from its relation to Normal Incidence SOUND Absorption Coefficient, which is:

$$\alpha_n = 1 - \left[\frac{z/\rho c - 1}{z/\rho c + 1}\right]^2$$

To find the two components of Acoustic Impedance—Acoustic Resistance and Acoustic Reactance—direct measurement is necessary. Sinusoidal plane sound waves are impinged on the specimen at the end of a long rigid tube, as in determining Sound Absorption Coefficient (C384-56T). A probe is used to determine the distance from the specimen to the first point of minimum amplitude on the standing wave (D_1), and the distance between two successive minimum points (D_2—half the wavelength of the frequency used). Specific Normal Acoustic Impedance is calculated by a formula of the following form:

$$z/\rho c = \coth\,(A + jB),$$

where A is a function of L ($\coth^{-1}[\log_{10}^{-1}(L/20)]$), B is a function of D_1/D_2 ($\pi[\frac{1}{2} - D_1/D_2]$), and j is $\sqrt{-1}$. Computational charts are available for determining Acoustic Resistance ($r/\rho c$) from values of L and Acoustic Reactance ($x/\rho c$) from values of D_1/D_2. Test frequencies are generally chosen from the series: 125, 250, 500, etc.

Acoustic Reactance, Resistance

Components of the ACOUSTIC Impedance of a material.

Arc Resistance

A measure of the resistance of the surface of an electrically insulating material to breakdown under electrical stress. The time in seconds during which an arc of increasing severity is applied intermittently to the surface until failure occurs. Not to be confused with DIELECTRIC Strength (the resistance of the material to electrical breakdown across its thickness). Failure may be one of four general types: 1) material becomes incandescent and hence capable of conducting current, regaining its insulating qualities upon cooling; 2) material bursts into flame, though no visible conducting path forms; 3) a thin wiry line ("tracking") forms between electrodes; or 4) surface carbonizes until there is sufficient carbon to carry current.

A more complete description of Arc Resistance can sometimes be obtained by tests *after* failure and return to normal temperature, specifically: 1) measuring the remaining Insulation RESISTANCE of the damaged area, or 2) repeating the Arc Resistance test and determining the Surface BREAKDOWN Ratio. This test is intended to simulate approximately the conditions existing in an a.c. circuit operating at high voltage but very small currents. Relative rankings of materials obtained are not necessarily the same for other types of arcs. Caution is necessary in making close comparisons except between very similar materials. A meaningful value of Arc Resistance cannot be obtained for all materials because of difficulties in observing a definite point of failure and because some materials melt, foul electrodes, flame or crack under the heat and stress.

The test (D495-58T) consists of resting two electrodes on the surface about ¼ in. apart and by means of a special circuit applying repeated arcing between the electrodes. Severity of arcing is increased at first by making the intermittent flashes more frequent, later by increasing current. Most of the older data available are based on a tungsten rod electrode, though a stainless steel strip electrode is now also standard; results obtained from the two are not necessarily comparable. The electrode tips rest on a ⅛-in. flat specimen, both at an angle of 35 deg from it, thus including a 110-deg angle. Pressure on specimen is controlled, total force of each tip being 50 gm. Open circuit voltage is 12,500 v. Arc frequency is increased during first 3 min, after which current is increased each minute by 10-ma increments to a level of 40 ma.

Breakdown Ratio, Surface

The ratio of ARC Resistance after tracking to Arc Resistance before tracking. Also called Surface Breakdown Voltage Ratio. It can be determined by allowing the specimen to cool after an Arc Resistance test, then repeating the test. Raising voltage in 100-v steps each sec is recommended in D495-58T. Surface Breakdown Ratio may determine whether an insulat-

ing material has to be replaced after the cause of an accidental arcing in service has been corrected.

Breakdown Voltage

The voltage at which a material fails in the DIELECTRIC Strength test.

Brightness

The relative amount of light reflected by a material. Brightness is measured by the reflectance of a material. See Luminous REFLECTANCE, Luminous Directional REFLECTANCE, Spectral REFLECTANCE, and Spectral Directional REFLECTANCE. For paper, Brightness is the 45-deg, 0-deg Luminous Directional REFLECTANCE (Reflectivity) when exposed to blue light—a measure of the freedom from yellowness of white and near-white paper. The value is reported separately for the wire and felt sides.

Capacitance

A material's capacity for storing electrical energy. Capacitance is often used in calculating DIELECTRIC Constant of a material. Since Dielectric Constant, by definition, is a ratio involving parallel capacitance, it is important that Capacitance in parallel, not in series, be used. Depending on the circuit used to determine Capacitance, conversion may be necessary.

Two basic types of tests (D150-54T) are used. A common type uses tuned or balanced circuits to compare the specimen with a known standard capacitor—generally a variable air condenser. The circuit is balanced first with the specimen connected in, then with the specimen disconnected. For the second balance it is necessary to increase the capacitance of the standard by an amount equal to the capacitance of the specimen. Variations of this method are used, including both resistive and inductive ratio-arm capacitance bridges, parallel-T networks, resonant circuits, and partially balanced networks with deflection measurement. Circuits requiring voltmeter, ammeter and wattmeter measurements are also used.

In the other basic test, the specimen is inserted in a variable air condenser itself—in this case a calibrated micrometer-electrode system. The specimen is placed between the micrometer electrodes and the circuit balanced or tuned, then removed and the system made to have the same capacitance by moving the micrometer electrodes closer together. Capacitance of the specimen is equal to the change in capacitance needed to rebalance the system, plus the air capacitance of the electrode system alone at a gap equal to the thickness of the specimen.

Capacity, Specific

An alternate term for DIELECTRIC constant.

Chromaticity Coordinates

Two of the three parameters commonly used in specifying COLOR and describing COLOR Difference.

Chromaticity Diagram

A plot of CHROMATICITY Coordinates useful in comparing the COLOR of materials.

Coercive Force

The magnetizing force (H_c) required to bring the induction of a material to zero, when the material is in a symmetrically, cyclically magnetized condition (see Normal INDUCTION). A low value is desirable for electromagnetic devices.

Coercive Force, Intrinsic

The magnetizing force (H_{ci}) required to bring the Intrinsic INDUCTION of a magnetic material to zero, when the material is in a symmetrically, cyclically magnetized condition.

How to Use This Glossary

Terms are in alphabetical order, as determined by the most significant word. Important terms within an entry are capitalized; most such terms are listed separately elsewhere in the glossary. Where cross reference to such a term would be helpful, its key word has been set in small capital letters, e.g., Magnetic HYSTERESIS Loop.

References to ASTM, Federal and TAPPI standards and specifications have been included in that order of preference. Because of the great number of references, the "ASTM" has been dropped from test designations; thus D150-54T means ASTM D150-54T. The references indicated should be consulted for details on conditioning procedure, the number of specimens used as the base, sampling procedure, reliability and reproducibility, statistical interpretation, and other procedural details.

Coercive Force, Relaxation

The reversed magnetizing force (H_{cr}) of such value that when it is reduced to zero, induction becomes zero (see Normal INDUCTION).

Coercivity

The maximum COERCIVE Force for a material (H_{cs}).

Color

The aspect of the appearance of a material which depends upon the spectral composition of the light reaching the retina of the eye and upon its temporal and spatial distribution. It has three attributes: HUE, LIGHTNESS and SATURATION.

Color of solid materials is generally measured in a spectrophotometer and determined from the Spectral TRANSMITTANCE of a light-transmitting material, the Spectral Directional REFLECTANCE of a light-reflecting material, or both properties for a translucent material—in each case given as a curve vs wavelength over the entire visible spectrum (D307-44, D791-54). The light source is a standard illuminant representing incandescent lamplight (A), sunlight (B) or average daylight (C), as desired. A standard method of designating Color by means of three parameters is widely used. The first parameter is the Luminous TRANSMITTANCE for light-transmitting materials, or the Luminous Directional REFLECTANCE (Reflectivity) for light-reflecting materials. The other two parameters are known as Chromaticity Coordinates.

For a reflecting (and not a self-luminous) material, the spectral composition of the reflected light is found by multiplying for each wavelength the spectral "irradiant" of the illuminant at that wavelength (H_λ, the relative intensity of that wavelength emitted by the illuminant, given in a table) by the Spectral Directional Reflectivity (R_λ) relative to magnesium oxide at that wavelength. This light, in turn, is evaluated on three scales (X, Y, Z) for each part of the spectrum by multiplying the $R_\lambda L_\lambda$ product by the scale value for unit irradiance, as established in a table (the ICI Standard Observer) representing the normal human eye. Scale values X, Y and Z are found by integration across the entire spectrum.

This manual supplements Manual No. 106, "Mechanical Properties and Tests," July '54, which is still in great demand as a reprint after five years.

The three defining parameters are then calculated from simple ratios of the three scale values. Thus, Luminous Directional Reflectivity (Reflectance) is the ratio between the Y parameters for the specimen and the standard. The x chromaticity coordinate is the ratio between the X scale value and the sum of the three scale values, and the y chromaticity coordinate is the ratio between the Y scale value and the sum of the three scale values. Sometimes the x and y Chromaticity Coordinates are plotted against each other (Chromaticity Diagram or Mixture Diagram) to help determine the relation of the color of a material to other known colors.

The same procedure is used for determining the three parameters for a light-transmitting material, except that Spectral Transmittance is used instead of Spectral Directional Reflectivity to determine the spectral composition of the transmitted light, and the ratio of the Y scale values is the Luminous Transmittance.

Color, Mass

The COLOR, when viewed by reflected light, of a pigmented coating of such thickness that it completely obscures the background. Sometimes called Over-Tone or Mass-Tone.

Color Difference

The difference in COLOR between two materials. Both quantitative and qualitative tests are used.

Quantitatively, Color Difference of opaque materials is commonly expressed as the vector sum of the measured differences in three components between the specimen and the reference material. The basic method (D1482-57T) consists of determining the CIE tristimulus scale values, X, Y and Z, for the reference and the specimen relative to magnesium oxide (see COLOR). These values are converted to Munsell color value functions V_X, V_Y and V_Z by an expansion equation, and the three vector components calculated by equations derived from the Adams-Nickerson equation, as follows: $L = 9.2\ V_Y$; $a = 40\ (V_X - V_Y)$; and $b = 16\ (V_Z - Y_Y)$. The components are expressed in Judds. The components for the reference are subtracted from those for the specimen, and the resultant components of Color Difference have both magnitude and direction. Thus, the L component, Lightness, is plus if the specimen is lighter, minus if it is darker; the a component is plus if the specimen is redder, minus if it is greener; and the b component is plus if the specimen is yellower, minus if it is bluer. Magnitude of the Average Color Difference is the square root of the sum of the squares of the three component differences.

With the "Color Eye" instrument (D1495-57T), the CIE tristimulus scale values are found by multiplying the tristimulus values of the instrument standard by the respective tristimulus values observed when the reflected light is "viewed" through three filters (X, Y, Z). The Hunter or Gardner Color Difference Meter (D1365-55T) gives direct scale readings of a, b and 45-deg, 0-deg Luminous Directional REFLECTANCE (R_d). The L component can be readily calculated; it is equal to $10\sqrt{R_d}$. This instrument also has an "alternate" scale which does not give the same results. The Hunter Multipurpose Reflectometer (D1260-55T) gives scale readings which must be converted by equations into the a, b and L components.

In judging Color Difference qualitatively, the method of Fed 141-4250 for dried, pigmented organic coatings is typical. The specimen and the reference are placed beside each other under 45-deg illumination substantially equal to that of a fairly light overcast northern sky. With adjacent colors excluded from view, the specimen and reference are compared by viewing normal to the surface. Where Specular GLOSS differs, the two films are first wet with water or heavy, water-white mineral oil.

Conductivity, Electrical

The ability of a material to conduct an electric current. The reciprocal of RESISTIVITY. Electrical Conductivity is often expressed in % based on a value of 100 for the International Annealed Copper Standard (IACS) which has a Resistivity of 10.371 ohm-cir mil/ft or 1.7241 microhm-cm at 68 F.

Conductivity, Thermal

The rate at which heat is transmitted through a material by conduction. See also thermal TRANSMITTANCE. The coefficient of heat transfer by conduction.

For materials that are not good conductors (i.e., where conductivity is not more than 30 Btu/sq ft/hr/°F/in.), Thermal Conductivity is commonly determined by measuring the heat expended in establishing a temperature gradient across two opposite faces of a specimen. For refractories (C201-47), a 9-in. dried, straight brick is placed in a heating chamber and guarded on all sides by refractory bricks to prevent side flow of heat. A thermocouple is embedded in each of two opposite faces of the specimen. In contact with the lower side of the specimen is a water calorimeter. The thermocouples and the water temperature are read several times at about 30-min intervals and averaged. Heat loss in Btu per hr is equal to the weight of calorimeter water in lb multiplied by its temperature rise in °F and divided by time in hr. Thermal Conductivity in Btu/hr/sq ft/°F/in. is equal to $qL/A\ (t_1 - t_2)$, where q is heat loss in Btu per hr, L is the thickness in in. of the brick between the hot thermocouple junctions, t_1 and t_2 are the two temperatures measured in °F, and A is the area of the calorimeter in sq ft. This method is used for insulating fire brick (C182-47) and fire clay refractories (C202-47).

A general method for insulating materials (C177-45) utilizes a guarded hot plate and is similar in most respects to the test for Thermal TRANSMITTANCE except that cool surface, not air, temperature is measured. A like approach is used for pipe insulation (C335-54T), the pipe being guarded to prevent end heat losses.

In a test used for whiteware ceramics at moderate temperatures (100-300 F), thermal conductivity is determined by comparing the rate of heat transfer in the ceramic with that in copper, for which Thermal Conductivity is known (C408-57T). The specimen, an accurately ground cylinder, is soldered to upper and lower copper "thermodes," thermocouples being located at both junctions and also about 2 in. away from these junctions in the copper. The entire system is subjected to a vacuum, constant heat applied to the upper thermode to establish a temperature gradient, and the thermocouples read after equilibrium is reached. Since the ratio of the thermal conductivities of copper and the specimen is proportional to the ratio of their respective temperature gradients and cross-sectional areas, and inversely proportional to the ratio of their respective gage lengths, Thermal Conductivity of the ceramic in Btu/hr/sq ft/°F/in. is equal to the ratio $(k_{cu}A_{cu}t_{cu}X_s)\,(A_st_sX_{cu})$, where k_{cu} is Thermal Conductivity of copper at the mean temperature of the upper thermode, A_{cu} and A_s are the cross-sectional areas of the copper and ceramic in sq ft, t_{cu} and t_s are the temperature differences in °F in the upper thermode and across the specimen, and X_{cu} and X_s are the lengths in in. across which the temperature differences are measured.

Conductivity Coefficient

See Thermal TRANSMITTANCE.

Contrast Ratio

A measure of Hiding Power or Opacity. The ratio of the reflectance of a material having a black backing to its reflectance with a white backing.

For coatings, a simple test (Fed 141-4122) consists of applying a coating of the desired dry film

thickness over both black and white carrara glass panels by means of a selected doctor blade, then determining the 45-deg, 0-deg Luminous Directional REFLECTANCE of each. Contrast Ratio of paper (TAPPI T425m-45) is determined in a similar way, but by viewing at an angle not more than 20 deg from the normal.

To determine the relationship between Contrast Ratio and coating thickness another test is used (Fed 141-4121). A known weight of coating material is brushed over the entire surface of a special chart having black and white portions and protected with a clear coating. Several such films are prepared, using different weights of coating material, and the Contrast Ratio for each determined as above. From the Specific GRAVITY of the coating material and the known weights, the applied thickness is calculated in ml per sq ft and plotted vs Contrast Ratio.

For porcelain enamels Contrast Ratio $C_{.80}$, i.e., the ratio of the reflectance of a coating over a black backing to its reflectance over a backing having a reflectance of 0.80, is commonly determined along with Coefficient of SCATTER (C347-57). The backing of 0.80 reflectance more closely approximates the metallic base used for porcelain enamels.

Core Loss, Specific

The power expended in a magnetic material subjected to a varying magnetizing force at a specified frequency. Its two components are EDDY Current Loss and HYSTERESIS Loss.

For currents up to 2000 cycles and inductions of 5 and 10 kilogausses, the specimen consists of Epstein strips assembled to form a square-sided core with double-lap joints (see Normal INDUCTION). For 60 cps and inductions of 10 and 15 kilogausses, the specimen (A343-54) consists of 22 lb of material built into a square frame with butt joints. Each solenoid has two windings—an a.c. primary and the induction secondary. An average voltmeter, a rms voltmeter and the voltage circuit of a wattmeter are connected across the secondary; the current circuit of the wattmeter is connected in the primary. A coupling transformer is used to vary frequency of the primary circuit. Primary current is adjusted to give the average or flux voltage predetermined to be necessary for the test induction, and the wattmeter and rms voltmeter are read. The wattmeter indicates the power consumed in both the specimen and the secondary circuit. Core Loss is calculated by subtracting the loss in the secondary circuit, which is equal to the square of the indicated rms voltage divided by the parallel resistance in ohms of the instruments in the secondary circuit. Specific Core Loss in w per lb or kg is equal to Core Loss divided by the weight of the core in lb or kg. A log-log plot of Specific Core Loss vs frequency for a given induction usually yields a straight line that can be extrapolated for practical purposes.

Specific Core Loss can be calculated the same way in the basic A.C. PERMEABILITY test. It can also be determined by the test used for Specific Incremental CORE Loss, simply by not energizing the d.c. winding, and by the test used for Effective A.C. PERMEABILITY (A346-58). In the latter case, Core Loss in w is equal to the square of the equivalent induced voltage (i.e., the measured secondary voltage referred to the primary winding) divided by the effective parallel resistance of the specimen in ohms, as indicated by the adjustable resistor. See also Incremental A.C. PERMEABILITY.

Core Loss, Specific Apparent

Apparent Core Loss is the product of the rms induced voltage and the rms exciting current (Rms EXCITATION) for a ferromagnetic core, where the induced voltage is approximately sinusoidal. Specific Apparent Core Loss in apparent w per lb or kg is Apparent Core Loss divided by the weight of the core.

Core Loss, Specific Incremental

The CORE Loss in a magnetic material when subjected simultaneously to a unidirectional ("biasing") and an alternating magnetizing force. Incremental Core Loss is determined by the two methods used for Incremental A.C. PERMEABILITY (A343-54). In the circuit bridge method, Incremental Core Loss is calculated from an equation in which it is proportional to the value of the variable condenser needed to balance the bridge. In the potentiometer method, Incremental Core Loss is equal to the product of the indicated in-phase current and equivalent induced voltage (i.e., the measured secondary voltage referred to the primary winding). Specific Incremental Core Loss is equal to Incremental Core Loss divided by the weight of the core. Specific CORE Loss can also be determined by these methods simply by not energizing the d.c. winding.

Core Loss, Standard

The Specific CORE Loss at an induction of 10 kilogausses and a frequency of 60 cps, designated P/10/60.

Covering Power

An alternate term for Opacity or Hiding Power of paints. See CONTRAST Ratio.

Curie Point

The temperature at which a metal or alloy ceases to be ferromagnetic when heated.

Demagnetizing Coefficient

The ratio (D_n) of 1) the extent to which an applied magnetizing force, as measured in a vacuum, exceeds the magnetizing force in a material, to 2) the extent to which the induction in a material exceeds the induction in a vacuum for the same magnetizing force (i.e., Intrinsic INDUCTION).

Demagnetizing Curve

The part of the Normal INDUCTION curve or HYSTERESIS Loop that lies between the Residual Induction point, B_r, and the Coercive Force point, H_c.

Density

The weight of a material per unit volume. Density in lb per cu ft or gm per cu cm is equal to Absolute Specific GRAVITY of the material at the desired temperature multiplied by the weight of 1 cu ft of water in lb, or the weight of 1 cu cm of water in gm at the same temperature. It is also equal to Specific GRAVITY multiplied by the difference in weight between a unit volume of air and a unit volume of water at the same temperature. The reciprocal of Specific Volume. Density may be calculated from Specific Gravity measurements, or in some cases measured directly by a liquid displacement method. For some materials it is more common to use Apparent DENSITY which is based solely on the ratio of weight to overall volume, including any entrapped air or gases. Thus, Density of a material is always greater than its Apparent Density. Density determined at one temperature can be converted to other temperatures provided that the Cubical Coefficient of THERMAL Expansion is known so that volume can be corrected.

Three types of direct tests for Density are commonly used: volumetric, dimensional measurement, and grading.

In the volumetric method, used for liquids, the volume of a pycnometer is calibrated against temperature using the known density of distilled water at various temperatures. The weighed bottle is filled with the liquid to a calibrated volume and the weight of the liquid determined. Density is equal to the weight of the liquid divided by its volume. This method is used for natural rubber latex (D1076-57T) and for paints (D1475-57T). Density of paints is usually converted to lb per gal. A modification of the

volumetric method—actually similar to the liquid displacement method used in determining Specific Gravity —is also used for latex. A weighed flask of calibrated volume is weighed when full of water, when half full of latex, and finally when the remainder of the calibrated volume is filled with water. The volume of water added is calculated from its weight and known Density. The calibrated volume of the flask minus the volume of water added is the volume of the latex. Density is calculated by dividing the weight of latex by its volume.

In the dimensional measurement method, the specimen is weighed in air and volume is calculated from measured dimensions. Density is equal to measured weight divided by calculated volume. This method is widely used for such materials as flexible foams (D1564-58T, D1565-58T), preformed block-type (C303-56) and pipe-covering-type (C302-56) thermal insulations, thin vulcanized fibre sheets (D619-54T), and core materials for structural sandwich constructions (C271-53). Density determined by this method is often termed Apparent Density because it does not take account of the surface nonuniformities of the material.

In the grading method, used for plastics (D1505-57T), the level to which the specimen sinks in a liquid column having a density gradient is compared with the level of a standard float of known density. A graduated tube containing solutions of four different densities is used. Density can be determined by interpolation or may be read directly from a predetermined graph of float position vs Density.

For hydrocarbon waxes, see Cubical Coefficient of THERMAL Expansion.

Density, Apparent

The apparent weight per unit volume of a more or less permeable material, based solely on overall weight-volume measurements. The specimen is weighed, usually in air, and volume is measured in a graduated container or calculated from dimensional measurements. Apparent Density in lb per cu ft or gm per cu cm is equal to the ratio of weight to volume. Apparent Density is the effective DENSITY of a material in a particular form. It is invariably less than the maximum theoretical Density of a material because the volume measured consists at least partly of air or another gas. It is analogous to Bulk Specific GRAVITY. Apparent Density is a useful test where only the effective Density is important or where the material is not suitable for liquid displacement methods of measuring Specific GRAVITY. Density determined by the dimensional measurement method is often called Apparent Density (e.g., electrical insulating paper, D202-55T) because it does not take account of the nonuniformities of the material.

Apparent Density is most commonly measured for molding powders; it is a measure of their fluffiness or bulk, and useful in calculating bulk factor for determining proper charges to the mold. Figures for Apparent Density are not comparable for the purpose of determining mold charge except for compounds having the same Specific GRAVITY after molding. Free-flowing metal powders (D212-48) are poured through a standard Hall flowmeter funnel into a 25-cm cylindrical cup. The cup is leveled and weighed, Apparent Density in gm per cu cm being the weight of the powder multiplied by 0.04. Granular thermoplastic molding powders (D1182-54) are poured freely into a 400-cu cm cylindrical cup. Molding powders used for molded electrical insulators (D392-38) are funneled freely into a 120-cu cm cup. Nonpouring molding powders (D954-50) are tested by dropping 60 gm loosely into a 3½-in. dia graduated cylinder from a specified height, allowing a 5-lb plunger to settle on the powder for 1 min, and calculating the resulting volume from the height. TFE resins require a different technique (D1457-56T) from other plastics because their particle shape is such that they pack very readily. The powder is screened into fractions, recombined, gently tumbled, fed into a 250-ml calibrated volumetric cup, and weighed. Apparent Density in gm per l is the weight of resin times 4. Refractory metal and compound powders (B329-58T) are tested by pouring the powder from a funnel into a 1-cu in. square, weighed cup through a box containing a series of baffle plates, leveling off the cup, and reweighing it to determine the weight of powder.

Density, Bulk

An alternate term for Apparent DENSITY. The term is used for refractory brick (D134-41, C20-46) and fired whiteware ceramics (C373-56); the property is determined by simple weight and dimensional measurements. The term is also used for granular refractories. Bulk Density of such materials (C357-55T) is determined by weighing about 25 cu cm of granules of specified screen size, soaking them in boiling water to saturate them, blotting off surface water, and pouring them into a known volume of water in a graduated cylinder. Dry weight is divided by the apparent increase in the volume of water.

Density, Green or Pressed

The DENSITY of an unsintered metal compact.

Density, Tap

The Apparent DENSITY of a powder obtained by measuring volume in a receptacle that is tapped or vibrated during loading in a specified manner.

Density, True

An alternate term for DENSITY, as opposed to Apparent DENSITY.

Dielectric Constant

A measure of the relative CAPACITANCE—i.e., the capacity for storing electrical energy—of a material. The ratio of 1) the parallel Capacitance of a given electrode configuration with the material as the dielectric, to 2) the Capacitance of the same electrode configuration with a vacuum as the dielectric. Also called Relative Permittivity and Specific Capacity. Low values of Dielectric Constant are desirable when a material is used as an insulator, high values when used in a capacitor. Dielectric Constant is useful in calculating the LOSS Factor.

Dielectric Constant is generally determined by measuring the parallel Capacitance of a material of known thickness and dividing by the known Capacitance of the same electrode system alone in a vacuum at a gap equal to the specimen thickness. To insure accurate measurement, a thin metallic film is applied to both sides of the specimen, eliminating minute air gaps between the surfaces of the electrodes and the material. The film may be conductive paint, fired-on silver, or sprayed or evaporated metal. As an alternative, mercury electrodes may be used. For accurate results at low frequencies, a guard electrode is generally used as in determining Insulation RESISTANCE.

Specimens are usually flat disks or rectangles. A 4-in. dia compression molded disk ⅛ in. thick is used for phenolic molding compounds (D700-57T). Rectangles ranging from 2 by 2 to 4 by 8 in., depending on thickness, are used for thermosetting laminates (D709-55T). Solid filling and treating compounds (D176-56T) may be tested in a cell at low frequencies, but are usually cast or pressed into disks or rectangles when tested for service at high frequencies and the lower part of their temperature range. Laminated sheet and plate insulation (D229-58) is generally tested both parallel and perpendicular to the laminations. In testing parallel to laminations (D669-42T), strips are stacked to form a pile 5¼ in. high which is then compressed in a frame. A common test frequency is 60 cps. Voltage is a maximum of 25 v per mil for varnished glass fabric (D902-56), 30 v per mil for

filling and treating compounds (D176-56T), and transformer and similar oils (D924-58), 50 v per mil for silicone rubber-coated glass fabric (D1458-57T), and 100 v per mil for cable oils (D924-58). The same methods can be used to test liquids in cells.

Dielectric Constant of polyethylene (D1531-58T) can be determined by a liquid displacement method, particularly suitable for values from 2.0 to 3.0 at room temperature and at frequencies from 1000 cps to 1 mc. The change in capacitance is measured when molded polyethylene specimens about 3 by 4 in. and 0.050 in. thick are inserted between two plates in a cell containing benzene. The change in capacitance is multiplied by the ratio of plate separation to specimen thickness, corrected by a constant factor for the cell, and added to the known Dielectric Constant for benzene to give the desired value of polyethylene. This method is nondestructive, fast and gives highly reproducible results. It is used for quality control and as an index of deterioration in various simulated service tests. The same method can be used to determine DISSIPATION Factor.

Dielectric Constant generally increases with temperature, humidity, exposure to weather, and deterioration. For most materials, Dielectric Constant varies considerably with frequency and to a lesser extent with voltage as a result of polarizations.

Dielectric Proof Voltage Test

An acceptance test, nondestructive to acceptable material (D1389-56T). The insulating material—usually plate, sheet or film—passes between two electrodes at a uniform rate. Proof voltage across the electrodes is generally selected as a percentage of the DIELECTRIC Strength (Short-Time) of the material or as a multiple of the dielectric breakdown of an air gap of equivalent thickness. Usually it is below the corona resistance level. Breakdown may be observed visually or indicated by tripping of a circuit breaker. Electrode diameters are 2 and 6 in., and material speed is either 7.5 or 25 fpm. Results are reported in terms of how often breakdown occurs.

Dielectric Strength

A measure of the ability of an insulating material to resist breakdown when subjected to electrical stress. The ratio of 1) the rms voltage gradient between two electrodes applied to opposite sides of the material, to 2) the thickness of the material. The Breakdown Voltage per unit thickness of material, ordinarily in v per mil. Breakdown occurs when a hole is punctured in the specimen (D149-55T). Since resistance to electrical stress decreases with exposure time, and varies with many other factors, the relatively short-time tests used to determine Dielectric Strength do not indicate the stress that material can withstand in service over a long period of time. The property is useful in comparing materials, in controlling processing of materials, and as a measure of contamination or deterioration. Four basic tests are used: Short-Time, Step-by-Step, Slow Rate of Rise (generally an alternate to Step-by-Step), and Long-Time.

In the Short-Time Test, voltage is increased from zero to breakdown at a uniform rate. For solid materials, the rate is usually 0.5 kv per sec. In a special Short-Time Test for rubber insulating tape (D119-57T) a 60 cps a.c. voltage of less than 1000 v is applied and voltage raised at the rate of 1000 v per sec. For insulating paper (D202-55T) the rate is chosen to give breakdown times of 10, 20 or 40 sec, depending on total breakdown voltage. The rate for insulating varnishes (D115-55) is chosen to give a breakdown time of 10 to 15 sec. A rate of 25 v per sec is used for anodically coated aluminum (D110-45), 0.1 kv per sec for solid filling and treating compounds used for electrical insulation (D176-56T), up to 0.5 kv per sec for cellulose acetate sheet (D1202-52T), 1 kv per sec for glass-bonded mica (D1039-58) and electrical porcelain (D116-44), and 3 kv per sec for insulating oils of petroleum origin (D877-49).

In the Step-by-Step Test, the initial voltage is equal to half of the Breakdown Voltage as determined by the Short-Time Test; voltage is then increased in equal increments and held for equal periods of time—usually 1 min—at each increment of voltage, until failure occurs. For thermosetting laminates (D709-55T) and other sheet and plate insulation (D229-58), voltage increments range from 1 to 10 kv, depending on initial voltage. For varnished glass (D902-56) and cotton (D295-58) fabrics, and for silicone rubber-coated glass fabric (D1458-57T), the rate is 12.5 v per sec (25 v per sec if thicker than 8 mils).

In the Slow Rate of Rise test, initial voltage is equal to half of the Breakdown Voltage as determined by the Short Time Test; voltage is then increased at a uniform rate until failure occurs. Specified rates are such that the product of voltage and exposure time is about the same as in the step-by-step test. For varnished glass (D902-56) and cotton (D295-58) fabrics, and for silicone rubber-coated glass fabric (D1458-57T), the rate is 12.5 v per sec (25 v per sec if thicker than 8 mils).

In the Long-Time Test, 1) voltage is held constant until failure occurs, or 2) voltage is applied for a long, but definite, period of time, then raised in increments and held at each successive voltage an equal period of time, until failure occurs. Exposure times up to 8 hr or more are used for cable insulation. In testing varnished cotton fabric (D295-58), material in the form of tape is wrapped on a brass tube and metal foil is used as the outer electrode. Initial voltage is 10% of the Breakdown Voltage as determined by the Short-Time Test, and temperature is 212 F. Voltage increments are 20% of initial voltage, and steps are 30 min each.

Electrodes vary in size and shape, depending on the material. Thick solid materials are cut down to reduce thickness. Solid materials may be tested in air or under oil, depending on where they are to be used. Liquids are tested in a cup. The specimen for phenolic molding compounds (D700-57T) is a disk ⅛ in. thick and 4 in. in dia. It is tested under oil between 1-in. dia cylindrical brass electrodes. Nonrigid vinyl tubing (D876-58T) may be tested whole or cut and flattened: small tubing is tested with a rod as the inner electrode and metal foil as the outer electrode; larger tubing is cut and flattened between two electrodes. Thermosetting laminates (D709-55T) and other sheet and plate (D229-58) may be tested either perpendicular or parallel to the flat sides. Results for laminates are reported as "parallel to laminations" or "perpendicular to laminations." Laminated rods (D349-56) are tested parallel to the axis. For parallel breakdown, a hole is drilled almost through the ½-in. width of the sheet specimen, leaving only 1/16 in. to be subject to the electrical stress. Insulating papers that are very thin or low in Dielectric Strength are stacked (D202-55T) to give more accurate values. Insulating varnishes are tested by applying a coating about 2 mils thick on copper sheets, and drying or baking as specified. In another method, used for silicone varnishes (D1346-57), a 7-mil film is applied and baked in two coats to a thin strip of glass fiber tape. In testing flexible treated sleeving (D350-57T), copper wire is used for the inner electrode and metal foil as the outer electrode.

Dielectric Strength (Short-Time) of pressure sensitive insulating tapes (D1000-58T), when obtained for widely varying moisture conditions, is an indication of the dielectric quality of the tape backing. In the case of anodized aluminum, the test can be used as an approximate measure of the thickness of the anodic coating, provided that the relationship between thickness and Dielectric Strength has been established for the particular type of anodic coating applied.

In general, Dielectric Strength increases as 1) rate of application of voltage increases, 2) diameter of electrodes increases, 3) thickness decreases, 4) temperature decreases, and 5) frequency decreases. Effect of frequency is small at low frequencies, but Dielectric Strength at radio frequencies may be as little as 10% of the value at 60 cps. Retention of Dielectric Strength—particularly under high humidity—is often more important than the original value.

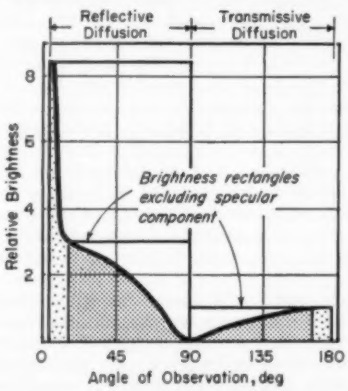
Diffuse Light Transmission Factor

The ratio of transmitted to incident light for translucent reinforced plastics building panels (D1494-57T). A flat or corrugated panel 24 by 24 in. is placed about 8 in. below a group of fluorescent tubes approximating ICI Illuminant C (average daylight). An acrylic diffusing plate is placed just above the specimen and a masking plate and photoelectric cell below the specimen. The galvanometer connected to the photoelectric cell is adjusted to read 100 with the specimen removed. With the specimen in position, Diffuse Light Transmission Factor is read directly from the galvanometer. This property is an arbitrary index of comparison and is not related directly to Luminous TRANSMITTANCE.

Diffusion Value

A measure of the reflective and transmissive diffusion characteristics of plastics (D636-54). An index of the scattering or diffusion of light by a material in comparison with a theoretically perfect light-scattering material (rated as 1.0). It is not used to measure transmissive scattering in essentially clear, transparent materials (see HAZE).

A flat specimen 0.050 in. thick—or a corrugated specimen with flat envelope—is mounted in a light-proof goniophotometer so that it is illuminated by a beam approximately normal to its face. A photosensitive receptor is rotated 180 deg around the specimen from a position normal to its lighted face to a position normal to its rear face, the intensity of the light reflected or transmitted at each angle being indicated by a galvanometer. The light scource is an incandescent tungsten filament at a temperature of 2800 to 3000 K. Angles of measurement are specified. Angles within 15 deg of the normal to either surface are used only if it is desired to include the specularly reflected or transmitted component of the light (Method A); if not they are omitted (Method B). The brightness readings are plotted as ordinates against angle of measurement, and a Brightness curve drawn. The areas under the reflectance curve and the



transmittance curve are determined separately. Then, in each case, a horizontal straight line is drawn at the maximum brightness reading and the area under this line, i.e., the area of the rectangle enclosing the Brightness curve, is determined. The Reflective Diffusion Value and Transmissive Diffusion Value, respectively, are the ratios of the areas under the reflectance and transmission curves to the areas of the corresponding maximum Brightness rectangles. The character of the surface of the material, i.e., polished, smooth, matte, grained, pebbled or configurated, should be reported; in some cases it is necessary to test the specimen in more than one direction to define its light diffusion properties accurately.

Diffusion properties of several materials can be compared graphically by converting maximum Brightness readings for each to 100 and "correcting" all readings by that ratio. The area under the curve for each material remains proportional to its diffusing power.

Dissipation Factor

The ratio of conductance to susceptance, or parallel reactance to parallel resistance, in a capacitor having the material as the dielectric. Also called Loss Tangent (tan δ; the tangent of the Loss Angle). Dissipation Factor is the cotangent of the PHASE Angle and the reciprocal of the Storage Factor (also called QUALITY Factor). Conventionally designated *D*, it is expressed in sec per cycle-ohm-farad. When materials have approximately the same DIELECTRIC Constant, Dissipation Factor indicates relative power loss. A low Dissipation Factor is generally desirable.

Dissipation Factor can be determined by connecting the material as the dielectric in a capacitor and measuring parallel reactance and parallel resistance by means of a balanced or tuned circuit. Dissipation Factor can also be determined by measuring parallel CAPACITANCE (C_p) and parallel resistance (R_p) and calculating $1/2\pi fR_pC_p$, where *f* is the frequency in cps. Specimens, voltages and frequencies are generally the same as those used in determining Dielectric Constant.

Dissipation Factor of polyethylene over a range of 0.0001 to 0.1 can be determined by a liquid displacement procedure (D1531-58T), also used in determining Dielectric Constant. The Dissipation Factor of the specimen in benzene is determined as above, and the Dissipation Factor of benzene subtracted. The resulting difference is multiplied by the ratio of plate distance to specimen thickness and added to the Dissipation Factor of benzene to give the desired value for polyethylene.

Under d.c. conditions, Dissipation Factor of dielectrics increases with humidity and exponentially with temperature. Dissipation Factor also increases with exposure to weather and deterioration. Voltage and frequency affect Dissipation Factor and are usually specified.

Eddy Current Loss

The part of CORE Loss that is due to current circulating in the magnetic material as a result of electromotive forces induced by varying induction (P_e).

Excitation, Rms

The rms alternating current required to produce a specified induction in a material. For inductions of less than 10 kilogausses, Rms Excitation (H_z) is usually expressed in oersteds; for high inductions, in amp-turns per in. A laminated core specimen is used (see Normal INDUCTION). The circuit of the coil primary is adjusted so that induction is indicated directly by a flux voltmeter. This is done by connecting the flux voltmeter across the secondary of a mutual inductor in the primary circuit and calibrating by means of calculations based on the cross-sectional area of the specimen. With the magnetizing force adjusted to give the desired induction, exciting current is read from an electronic voltmeter or ammeter. With windings and circuit as specified in A346-58, H_z in oersteds is 10 times the voltage indication or 14 times the current indication; in amp-turns per in., 10 times the voltage indication or 20 times the current indication. Tests at 60 cps are usually made at 100, 6000, 10,000

or 15,000 gausses. Permeability calculated on the basis of Rms Excitation as magnetizing force is known as Apparent Impedance Permeability. Rms Excitation per lb can also be calculated.

Flexivity

An index to the change in flexure with temperature of thermostat bimetals (D106-56). The change of the curvature of the longitudinal centerline of the specimen per unit temperature change per unit thickness. The metal strip is supported with a span of 2½ to 5 in. depending on thickness, heated, and deflection measured by means of a transmission rod connected to a dial gage or by an optical sight method. Radius of curvature at any temperature is determined by a trigonometric equation relating specimen thickness, span distance and vertical deflection. Radii of curvature (R_1, R_2) are determined for two temperatures (T_1, T_2), and Flexivity is calculated equal to $t(1/R_2 - 1/R_1)$ $(T_2 - T_1)$, where t is thickness.

Freezing Point

The temperature at which a material solidifies on cooling from the molten state under equilibrium conditions. The MELTING Point as determined in cooling.

Gloss, Apparent

A measure of the shininess of a material. Quantitatively, gloss is measured as Specular GLOSS. A simple qualitative test for Apparent Gloss is standard for nitrocellulose clear lacquers and lacquer enamels (D333-40). The test material and a reference standard are flowed onto an opaque surface side by side. After drying, the test panel is held up to a lamp at an angle of incidence approaching 90 deg, i.e., nearly parallel to the surface, and the comparative sharpness of definition of the image (i.e., the filament) noted.

Gloss, Specular

A measure of the shininess of the surface of a material. The ratio of 1) the light reflected by a material at an angle corresponding to the mirror image of the incident beam, to 2) the incident light. The luminous fractional reflectance of a material at the specular direction.

A standard source of light and a specified aperture are used to throw a beam of light on a flat specimen, and a photosensitive receptor connected to a galvanometer is positioned at the mirror-image angle to measure reflection. The incident light is determined by measuring the normal reflectance of a standard (a highly polished, plane, black glass surface or a "working" standard calibrated against it).

The most common angle for gloss measurements is 60 deg from the normal. For nonmetallic materials (D523-53T) having a 60-deg gloss higher than 70, 20-deg gloss is also determined. For nonmetallic materials having a 60-deg gloss lower than 30, 85-deg gloss (sometimes called Sheen) is also determined. A better correlation with visual estimates of Gloss can sometimes be obtained with a two-aperture 60-deg test originally developed for clear finishes on wood (D1471-57T). Readings are taken with the large aperture (G_L), then with the small (G_S). Where two materials have about the same large-aperture value but not the same appearance, the difference in small-aperture values indicates the relative scattering of the materials. The material with the lower small-aperture value has more narrow-angle scattering, i.e., poorer image-forming characteristics.

For paper (D1223-52T), 75-deg Gloss is widely used as a partial measure of surface quality and shiny appearance.

For ceramics and porcelain enameled materials, 45-deg Gloss is commonly measured (C346-55T), the ratio being multiplied by 1000. Sometimes the 45-deg Gloss is "corrected" to eliminate the "body reflected component," thus making the result a better index to surface reflection. The body reflected component is measured by either 1) measuring the reflection at 45 deg when the material is illuminated at 0 deg (normal), or 2) determining the 45-deg, 0-deg Luminous Directional REFLECTANCE and multiplying it by 5.5. This value is subtracted from the measured Specular Gloss to give the surface reflected component.

Gravity, Absolute Specific

The ratio of the weight in a vacuum of a given volume of material to the weight in a vacuum of an equal volume of gas-free distilled water. The temperature of the material and the water need not be the same, but must be stated (where two temperatures are given, the first is for the material, the second for the water). Sometimes called simply "specific gravity," but not the same as Specific GRAVITY which is based on weight measurements in air. For practical purposes, Specific Gravity is more commonly used.

Gravity, Apparent Specific

The ratio of the weight in air of a given volume of the impermeable portion of a permeable material to the weight in air of an equal volume of gas-free distilled water. The temperature of the material and the water need not be the same, but must be stated (where two temperatures are given, the first is for the material, the second for the water). The volume includes impermeable pores or voids. The term is also used interchangeably with Specific GRAVITY, though they are not the same. Typical of its determination is the Apparent POROSITY test used for fired whiteware ceramics (C373-56) and burned refractory brick (C20-46). In addition to dry weight, the weight of the saturated specimen suspended in water is determined. The loss in weight in gm is the weight of water having a volume equal to that of the impervious portion of the material.

Gravity, Bulk Specific

The ratio of the weight in air of a given volume of a permeable material to the weight in air of an equal volume of gas-free distilled water. The temperature of the material and the water need not be the same, but must be stated (where two temperatures are given, the first is for the material, the second for the water). The volume includes both permeable and impermeable voids normal to the material. Bulk Specific Gravity is analogous to Apparent DENSITY and Bulk DENSITY.

Gravity, Specific

The ratio of the weight in air of a given volume of a material to the weight in air of an equal volume of gas-free distilled water. The temperature of the material and the water need not be the same, but must be stated (where two temperatures are given, the first is for the material, the second for water). Sometimes called "apparent specific gravity." Not the same as Absolute Specific Gravity, which is based on weight measurements in a vacuum. See also Apparent Specific GRAVITY and Bulk Specific GRAVITY. Specific Gravity is sometimes used in determining impurity, gas or void content of a material. The extent to which measured Specific Gravity differs from the theoretical Specific Gravity of a material is an indication of the presence of impurities of higher or lower Specific Gravity.

Two basic methods are used for solids: liquid displacement and change in weight. In the liquid displacement method, specimen weight a is determined. Then a pycnometer is weighed (b) when filled with water or other displacement liquid of known specific gravity d, and when filled with the displacement liquid and containing the specimen (c). The weight of the liquid displaced by the specimen is $(a + b - c)$, and its volume, and the volume of the specimen, is $(a + b - c)/d$. Specific Gravity of the material is equal to specimen weight a divided by the calculated volume. This method is particularly useful for granu-

lar materials. It is used for plastics molding powder, flakes, and pellets (D792-50), solid filling and treating compounds for electrical insulation (D176-56T), granular refractories (C135-47), and fired whiteware ceramics (C329-56). In testing carbon, benzene is used as the displacement liquid, and a vacuum is applied to the pycnometer to remove adsorbed air from the carbon before liquid volume is adjusted. In testing fired whiteware ceramics (C329-56) and refractories (C135-47), the material is ground to a specified screen size and dried before weighing.

In the change in weight method, the specimen is suspended from a wire, weighed in air, and then, still suspended, completely immersed in water and weighed. Weight in water is corrected to compensate for the loss in weight of the wire in water. Specific Gravity of the material is equal to the weight of the specimen in air divided by its corrected loss of weight in water. If a liquid other than water is used, its Specific Gravity must be known and used to correct the ratio determined. This method is useful for most solid materials, including plastics sheet, rods, tubes, moldings and machined shapes (D792-50), and cemented carbides (D311-58). In testing sintered metal powder parts (D328-58T), an oil-free part is impregnated with oil before determining its change in weight in water. Specific Gravity of the oil-free part is equal to its weight in air divided by the change in weight of the oil-impregnated part (equivalent to the weight of an equal volume of water). For oil-impregnated parts, the method is the same except that weight in air is the weight of the oil-impregnated part.

Three methods are commonly used for liquids: plummet displacement, volumetric and hydrometer. In the plummet displacement method an aluminum plummet weighing 5-10 gm is calibrated by the change in weight method (above) to determine its weight of water displacement, using cubical Coefficient of THERMAL Expansion of aluminum to correct the displacement to the desired test temperature. Then the weight of the plummet suspended in the liquid is determined. Specific Gravity of the liquid is equal to the change in weight of the plummet divided by its previously determined displacement weight as corrected for temperature. This method is used for testing filling and treating compounds for electrical insulation in their liquid state (D176-56T).

In the volumetric method, the weight of a known volume of the liquid is determined in a calibrated pycnometer. Specific Gravity of the liquid is equal to the measured weight divided by the weight of an equal volume of distilled water. This method is commonly used for insulating varnishes (D115-55).

In the hydrometer method, a floating glass hydrometer, calibrated in terms of Specific Gravity, is inserted in the liquid slightly further than its rest position and allowed to come to rest. Specific Gravity is read directly. This method is commonly used for askarels (D901-56). Usual test temperature for askarels is 60 F for low viscosities, 194 F for high viscosities.

Haze

A measure of the extent to which light is diffused in passing through a transparent material. The percentage of transmitted light which in passing through the material deviates from the incident beam by forward scattering. In the standard test for Haze of transparent plastics (below), only light deviating more than 2.5 deg is considered Haze.

For transparent plastics having Haze values less than 30%, two methods (D1003-52) are used. The specimen is a clean, blemish-free, void-free disk about 1⅜ in. in dia. Procedure A uses a haze meter—essentially a unidirectional light source, an integrating sphere for collecting transmitted light flux, a light trap, and a photoelectric cell connected to a galvanometer for light measurements. First the incident light (T_1) is determined by measuring the light reflected from a reflectance standard at an aperture in the sphere. Next, with the standard still in position, the specimen is placed over a 1-in. aperture in the sphere in the beam path and the total light passing through it (T_2) is measured. Then, with neither the specimen nor the standard in position, the light trap is placed in position and the amount of light scattered by the instrument (T_3) is measured. Finally, with only the specimen in position, the light scattered by the instrument and the specimen (T_4) are measured, i.e., the light in the sphere. Total transmittance is the ratio T_2/T_1. The light scattered by the instrument, T_3, is corrected by multiplying by Total Transmittance, T_2/T_1, and the result subtracted from T_4 to give the light scattered by the specimen. Diffuse Transmittance is equal to this value divided by incident light T_1. Haze is the ratio of Diffuse Transmittance to Total Transmittance, expressed in %. The standard illuminant (A or C) used in the test must be reported.

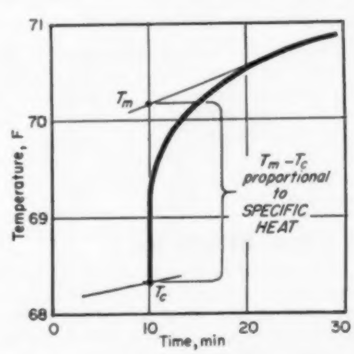
In Procedure B, the approach is similar except that a recording spectrophotometer is used to record curves vs wavelength for each of the four conditions, and the values are computed by integrating across the entire visible spectrum (see COLOR). Thus Haze becomes the ratio of Diffuse Luminous TRANSMITTANCE to Total Luminous TRANSMITTANCE, expressed in %.

Heat, Specific

A component of the THERMAL Diffusivity of a material. The quantity of heat required to change the temperature of a unit mass of material 1 deg, commonly expressed in Btu/lb/°F. Numerically, Specific Heat is the same in both England and cgs (i.e. cal/gm/°C) units, since the unit of heat are defined in terms of Specific Heat. Mean Specific Heat is the average Specific Heat over a specified temperature range.

Essentially, Specific Heat is determined in a calorimeter by heating a known weight of the material to a known elevated temperature, adding it to a known weight of water at a known low temperature, and measuring the resulting equilibrium temperature. By equating the heat absorbed by the water and the containing vessel to the heat given up by the hot material, the Specific Heat of the material can be calculated by dividing its heat loss by its weight and temperature change.

In practice (C351-54T), the "water equivalent" of the calorimeter—i.e., the mass of water that requires the same amount of heat as the calorimeter for a given temperature change—is first determined using a Specific Heat standard. Then a weighed amount of water, about 300 gm, is poured into the calorimeter. The dried and weighed specimen is placed in a capsule, heated to a measured temperature, then lowered rapidly into the water, and water temperature measured at 1-min intervals until a plot of water temp-



erature vs time shows a constant slope over a 10-min period. The original temperature of the water is actually determined by regular readings vs time be-

fore mixing and extrapolating the curve ahead to the time of mixing. The equilibrium temperature of the mixture is determined by extrapolating the final slope back to the time of mixing. The thermal exchange that takes place during the first minute is considered instantaneous and is proportional to the temperature difference read from the graph. The amount of heat absorbed by the water and calorimeter—and thus the amount given up by the specimen and the capsule—is equal to weight (i.e., weight of water plus "water equivalent" of the calorimeter) multiplied by increase in temperature multiplied by the Specific Heat of water. Dividing by the drop in temperature of the capsule gives the thermal capacity of the capsule and specimen, and subtracting the product of capsule weight and capsule Specific Heat gives the thermal capacity of the specimen. Dividing by the mass of the specimen gives the Specific Heat of the material.

Heat of Fusion

The amount of heat per unit weight absorbed by a material in melting.

Hiding Power

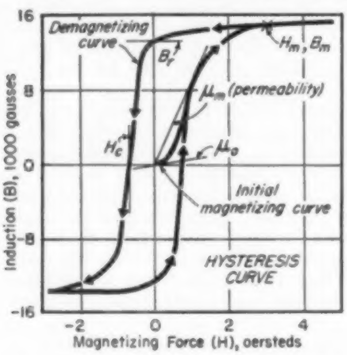
The ability of a paint to obscure a surface. Also called Opacity. Usually measured by the CONTRAST Ratio.

Hue

The attribute of COLOR which determines its position in the wavelength spectrum, i.e., whether it is red, yellow, green, blue, violet, etc.

Hysteresis Loop, Magnetic

A curve showing the relationship between magnetizing force and magnetic induction in a material which is in a cyclically magnetized condition. For each value and direction of the magnetizing force, there are two values of induction—one when the magnetizing force is increasing and one when the magnetizing force is decreasing. The result is actually two smooth curves joined at the ends to form a loop. The area within



the loop represents the energy expended in the material in the form of heat. Where an alternating current is used, the loop indicates the amount of energy transformed into heat during each cycle of current. The Magnetic Hysteresis Loop is commonly determined by means of Normal INDUCTION measurements. From it can be read the values of Residual INDUCTION (B_r) and COERCIVE Force (H_c).

Hysteresis Loss, Magnetic

The power (P_h) expended in a magnetic material as a result of magnetic hysteresis when induction is cyclic. The enclosed area of the Magnetic HYSTERESIS Loop. It is one component of the Specific CORE Loss and is a function of COERCIVITY and RETENTIVITY.

Impedance Permeability, Apparent

See Rms EXCITATION.

Induction, Intrinsic

The extent to which induction in a magnetic material exceeds induction in a vacuum for a particular magnetizing force (B_i). The measured induction minus the product of the magnetizing force and the Permeability of a vacuum. In the cgs electromagnetic system (gausses, oersteds), the Permeability of a vacuum is arbitrarily taken as unity, so that Intrinsic Induction is numerically equal to Normal Induction minus magnetizing force. Intrinsic Induction is sometimes plotted against magnetizing force.

Induction, Normal

The limiting induction—in either direction—of a material which is in a symmetrically, cyclically magnetized condition. The magnetic material is placed within a coil. A magnetizing force is applied by sending current through the primary winding, force being proportional to the current and the number of turns on the winding. The resulting magnetic flux induces a voltage in a secondary winding which is connected to a previously calibrated galvanometer, the galvanometer deflection being proportional to the flux density or induction. Induction is measured for both increasing and decreasing magnetizing force, and for magnetizing force in both directions, to develop Magnetizing and Demagnetizing Curves. Complete Magnetizing and Demagnetizing Curves form a Magnetic HYSTERESIS Loop. Other important properties that can be determined from a Normal Induction curve include Residual INDUCTION, COERCIVE Force and Normal PERMEABILITY.

Three different methods (A341-55) are used to measure Normal Induction, dependent somewhat upon the nature of the material and its form. In the permeameter method, the specimen consists of a stack of 4 to 12 strips, the number increasing as thickness decreases. A number of commercial instruments are available. For rings of magnetic materials—particularly soft materials not requiring high magnetizing forces— the Rowland Ring method is used. The method is suitable for materials having directional properties provided orientation can be made circumferential around the ring. The secondary or flux coil is wound directly on the ring, and the primary or magnetizing coil is wound over it.

The electrical circuit is essentially the same for all three methods. Magnetizing force is determined by calibration using a mutual inductor in the permeameter method, and by calculations based on the length of the magnetic path in the Rowland and Epstein methods. Induction is determined in all three methods by calibration of the secondary circuit in terms of a known inductor. The third method, known as the Epstein Double-Lap Joints test, is used for flat rolled magnetic materials. The specimen consists of strips about 11 to 20 in. long. Number of strips ranges from 20 to 50, increasing as thickness decreases. The strips are assembled in a square frame consisting of four solenoids, each having two windings. In each corner of the frame the strips of adjacent sides overlap and are clamped together. The opposite solenoids contain strips cut in the same manner, i.e., parallel or perpendicular to the rolling direction.

Induction, Residual

A measure of the permanence of magnetization in a material. The magnetic induction (B_r) corresponding to zero magnetizing force in a magnetic material which is in a symmetrically, cyclically magnetized condition. The induction at either of the two points where the Magnetic HYSTERESIS Loop intersects the B axis. It is determined from Normal INDUCTION data. See also RETENTIVITY.

Induction, Saturation

The maximum Intrinsic INDUCTION possible in a material (B_s).

Insulation Ratio, Effective

See Thermal TRANSMITTANCE.

Iron Loss

An alternate term for Specific Core Loss (see Specific CORE Loss).

Lamination Factor

A measure of the effective volume of a laminated structure, in particular (A344-52) a laminated structure composed of strips of magnetic material. The ratio of the volume of the structure as calculated from the weight and DENSITY of the strips, to the measured solid volume of the structure under pressure. Given a certain required mass of metal, and assuming strips equivalent in number and thickness, the actual depth of a laminated structure can be calculated by dividing theoretical depth (i.e., the product of strip thickness and number of strips) by this ratio. The difference in volume, i.e., the difference between the ratio and 1.0, is a measure of the total effect of such factors as oxides, roughness and insulating coatings in preventing perfect planar contact between the strip surfaces. Strips about 10 in. long and 1³⁄₁₆ in. wide are weighed, then stacked between two plates and subjected to 50-psi uniform compression. A stack may consist of 24 to 100 strips, the number increasing as strip thickness decreases. Volume under pressure is calculated by multiplying strip area by the distance between faces of the compression plates while under pressure.

Lightness

The attribute of COLOR which permits any color to be classified as equivalent to some member of the series of grays ranging between black and white. The term SHADE is often used to describe differences in Lightness. Lightness difference is measured as part of the COLOR Difference test.

Line of Sight, Deviation of

The extent to which line of sight is displaced when a target is sighted through flat or curved sections made of transparent plastics (D881-48), generally in terms of angular deviation. A telescope is focused on a ruled target. The specimen is placed in the line of sight and the apparent shift in the position of the telescope crosshairs on the target noted. Angular deviation in min is equal to 3440 Ns/L, where N is the number of rulings apparently shifted, s is the ruling spacing in in., and L is the distance in in. between the target and the part of the specimen being examined. The deviation depends both on the angle of incidence and the lack of parallelism of the surfaces, if any. Angle of incidence is generally chosen to simulate service.

Liquidus Temperature

The temperature at which an alloy finishes melting during heating or starts freezing during cooling, under equilibrium conditions. For pure metals, the same as the SOLIDUS Temperature and known simply as the MELTING Point. Effective Liquidus Temperature is raised by fast heating and lowered by fast cooling.

Loss Angle

A measure of the electrical power loss in an insulating material subjected to a.c. current. The arctangent of the DISSIPATION Factor, and thus the angle between a material's parallel resistance and its total parallel impedance in a vector diagram when the material is used as the dielectric in a capacitor. Complement of a material's PHASE Angle. Sometimes called Phase Defect angle. Conventionally designated δ.

Loss Factor

A measure of the electrical power loss in an insulating material subjected to a.c. current. The product of the DISSIPATION Factor and the DIELECTRIC Constant. It is proportional to the energy loss per cycle per unit volume per squared potential gradient. Conventionally designated *DK*, it is expressed in the same units as Dissipation Factor (sec per cycle-ohm-farad). A low Loss Factor is desirable for high frequencies; for a given value of Loss Factor, power loss increases directly with frequency.

A low Loss Factor is generally desirable for a material, either as an insulator or as a capacitor dielectric, to reduce heating and minimize electrical effects on the rest of the network. Sometimes Loss Factor is deliberately increased in an insulating material, usually by increasing Electrical Conductivity, to reduce the voltage gradient. Loss Factor generally increases with humidity, weathering, deterioration and exponentially with temperature. It also varies considerably with frequency.

Luminous Reflectance, Transmittance

See Luminous REFLECTANCE, Luminous Directional REFLECTANCE, Luminous TRANSMITTANCE and Diffuse Luminous TRANSMITTANCE.

Magnetic Energy Product, Maximum

The maximum external energy that contributes to the magnetization of a material. It corresponds to the maximum value of the abscissa for the MAGNETIC Energy Product Curve.

Magnetic Energy Product Curve

The curve obtained by plotting the product of induction and demagnetizing force against corresponding values of induction, i.e., the product of the coordinates of the Demagnetizing Curve (B_d,H_d) as the abcissa vs induction (B_d) as the ordinate.

Mass-Tone

An alternate term for Mass COLOR.

Melting Point

For a pure metal, the temperature at which liquefaction occurs on heating or solidification occurs on cooling under equilibrium conditions. Under slow heating or cooling, the temperature is easily observed because the isothermal absorption or evolution of the Heat of Fusion at that temperature interrupts the heating or COOLING Curve abruptly. Alloys and other materials have a MELTING Range, and Melting Point is often defined as the temperature near the bottom of this range at which an observable change caused by melting occurs.

In general, Melting Point is determined by heating a small specimen fairly rapidly in a crucible or other suitable container to a temperature not too far below the Melting Point, then raising temperature slowly—a few degrees a minute—and watching closely for the first indication of liquefaction.

For nylon, Melting Point is determined with a Fischer-Johns apparatus No. 12-142 (D789-53T). A thin shaving is placed between cover glasses and heated on an aluminum stage. Near the melting point, temperature is increased 3.6 °F per min.

For TFE, Melting Point is defined (D1457-56T) as the temperature at which a shaving changes from milky white to gray translucent at the outer edges. The piece, shaved from a molded disk, is 10-15 mils thick, 50-70 mils wide, and ½-¾ in. long. Temperature is increased at 1.8 °F per min above 590 F.

For filling and treating compounds used for electrical insulation (D176-56T), Melting Point is defined as the temperature at which the material becomes fluid enough to drop off the bulb of a thermometer (D127-49). The chilled bulb is inserted in the molten material to coat it, then removed from heat until the coating solidifies. The thermometer is brought to 60 F, and temperature increased gradually—3 °F per min to 100 F, 2 °F per min above 100 F—to the Melting Point.

Melting Range

The range of temperature between the SOLIDUS Temperature and the LIQUIDUS Temperature for an alloy.

Neutron Absorption Cross Section

Also called Neutron Capture Cross Section. A measure of the probability that a single nucleus of a material subjected to nuclear bombardment will intercept and interact with an incoming neutron. Expressed in sq cm, the fraction of neutrons contained in a beam of 1-sq cm cross section that can be expected to be intercepted by a single nucleus. Effective Neutron Absorption Cross Section depends on the level of incident energy; for fast neutron scattering, it approximates the theoretical area of the nucleus. The common units are barns per atom, where 1 barn is equal to 10^{-24} sq cm. A low cross section is desirable for nuclear reactor core materials, a high value for reactor shielding.

Opacity

The degree to which a material or coating obstructs the transmittance of visible light. The term is used primarily in connection with nearly opaque materials, for which Opacity is generally reported in terms of the CONTRAST Ratio. Opacity of light-transmitting materials is usually expressed in terms of its opposite or complementary property, i.e., Total TRANSMITTANCE or Diffuse Light TRANSMISSION Factor.

Over-Tone

An alternate term for Mass COLOR.

Permeability, A.C.

An index of the ease of magnetization of a material. The ratio of the maximum value of induction to the maximum value of the magnetizing force for a material which is in a symmetrically cyclically magnetized condition. The specimen (A343-54) consists of Epstein strips assembled to form a square-sided core with double-lap joints (see Normal INDUCTION). Because of the sinusoidal wave form of a.c. current, it is necessary to use a special technique to obtain a maximum force value rather than a value proportional to rms current. A flux voltmeter is connected across the secondary of a mutual inductor in the primary circuit, and calibrated in terms of crest magnetizing current, since its reading will be proportional to crest current. Using the flux voltmeter as an indicator, primary voltage is adjusted to a calculated value proportional to maximum induction and to the specimen's cross-sectional area. Air flux is compensated for by calculation or by balancing it off with a mutual inductor. Magnetizing force is calculated, being proportional to crest magnetizing current and number of turns on the primary, and inversely proportional to the length of the magnetic path. A.C. Permeability is the ratio of 1) the maximum induction value used in calculating applied voltage to 2) the calculated crest magnetizing force. Tests at 60 cps are usually made at inductions of 10 and 15 kilogausses. The same test can be used to determine Specific A.C. CORE Loss by connecting in a wattmeter. Two other methods used to determine Incremental A.C. PERMEABILITY can also be used to determine A.C. Permeability simply by not energizing the d.c. winding on the coil.

Permeability, Apparent Impedance

An index of the ease of magnetization of a material. The ratio of induction to Rms EXCITATION in a material which is symmetrically cyclically magnetized.

Permeability, Effective A.C.

An index of the ease of magnetization of a material. A.C. PERMEABILITY as indicated by the capacitance needed to balance the effective inductance of the material when magnetized as a core. The test (A346-58) assumes that the impedance of the primary can be made equivalent to a network of resistance and inductance components. A laminated core specimen (see Normal INDUCTION) is used. The bridge circuit is adjusted so that an adjustable resistor balances the effective resistance of the core specimen and an adjustable condenser balances the effective inductance of the core specimen. The resistance and inductance of the winding alone are balanced off by a preset resistor and condenser. By calculations based on length of magnetic path, cross-sectional area of the specimen, induction and applied voltage, the bridge is calibrated to give permeability values directly from the variable condenser reading. Tests at 60 cps are usually made at inductions of 40, 100, 200 or 6000 gausses. This method is also used to determine Specific CORE Loss, using the effective parallel resistance of the specimen, and Specific REACTIVE Power. Incremental A.C. PERMEABILITY can also be determined, using d.c. forces of 0.25, 1 and 5 oersteds.

Permeability, Incremental A.C.

When compared with normal A.C. PERMEABILITY, an index of the increase in mean induction that can be expected when a.c. magnetization is superimposed upon d.c. magnetization. Two methods (A343-54) are used, the specimen in both cases consisting of Epstein strips assembled to form a square-sided core with double-lap joints (see Normal INDUCTION). Each solenoid has three windings—an a.c. primary, the induction secondary, and a d.c. primary. A d.c. magnetizing force of up to 2 oersteds is applied. A predetermined a.c. voltage, proportional to maximum induction and the specimen's cross-sectional area, is applied. When the a.c. magnetizing current is superimposed on a d.c. current, it is common to use 10 gausses at either 60 or 1000 cycles. With a.c., alone, 10 or 1000 gausses at 60 cycles, or 10 gausses at 1000 cycles, are used.

In one method a circuit bridge is balanced by means of a condenser and resistor in parallel. Incremental A.C. Permeability is calculated from the value of the variable resistor in an induction-force equation containing a constant for the bridge. Specific CORE Loss can be calculated from the value of the variable condenser, and Specific REACTIVE Power from the value of the variable resistor and the current frequency. This method can also be used to determine Normal INDUCTION.

In the other method, a potentiometer is connected across the secondary winding and adjusted so that the in-phase dial indicates total voltage and the quadrature dial reads zero. When primary voltage is set to give calculated induction, the potentiometer is connected to a resistor and read. In-phase voltage is the power component; quadrature voltage is the magnetizing component. Corresponding currents are calculated by Ohm's Law using the series resistance. Incremental Permeability is calculated from an induction-force equation and is inversely proportional to the quadrature current. Incremental A.C. CORE Loss can be calculated from the in-phase current, and Incremental REACTIVE Power from the quadrature current.

Both of these methods can be used to determine A.C. Normal PERMEABILITY, Specific A.C. CORE Loss and Specific REACTIVE Power simply by not energizing the d.c. winding on the coil. See also Effective A.C. PERMEABILITY.

Permeability, Initial

The slope of the Normal INDUCTION curve at zero magnetizing force (μ_o).

Permeability, Intrinsic

The ratio of Intrinsic INDUCTION to the corresponding magnetizing force (μ_i).

Permeability, Maximum

The maximum value of Normal PERMEABILITY for a magnetic material (μ_m).

Permeability, Normal

An index of the ease of magnetization of a material. The ratio of Normal INDUCTION to corresponding magnetizing force (μ). The slope of the magnetizing or Normal Induction curve at a specified value of magnetizing force. See also A.C. PERMEABILITY.

Four methods (A342-53) are used to determine the Normal Permeability of feebly magnetic materials, i.e., materials having a Normal Permeability not exceeding 4.0. Each test determines Intrinsic Permeability, i.e., the ratio between Intrinsic INDUCTION and the corresponding magnetizing force. Normal Permeability is equal to Intrinsic Permeability plus the permeability of a vacuum, which in the cgs system (gausses, oersteds) is taken as 1.0.

In three methods, Intrinsic Induction is determined by energizing a coil, adjusting the secondary circuit of the coil to balance off the air flux, then inserting the specimen and measuring the flux density or induction of the material alone.

Method No. 1 uses a permeameter consisting of a magnetizing solenoid with two test coils measuring magnetizing force and induction. The specimen may be straight bar, rod, wire or strip; the ratio of length to diameter or equivalent diameter depends on the permeability range and is specified. Magnetizing force and induction are calibrated in terms of a standard inductor. Air flux is balanced by means of a compensating coil. In Method No. 2, a balancing resistor and a special switch are used for flux compensation. In Method No. 3 a compensating inductor is used to balance the air flux, and induction is measured in terms of the change in a variable inductor needed to null-balance the voltage in the secondary circuit after the specimen has been inserted in the coil.

Method No. 4 is suitable only for paramagnetic materials, i.e., materials having permeability less than 1.05. The specimen may be straight bar, rod, wire, strip or tube of uniform cross section at least 2½ in. long and no more than ½ in. wide. It is suspended from a scale balance so that the lower end is close to the center of the air gap in an electromagnet. The specimen is weighed without the magnet energized, then with applied magnetizing forces of 500 and 1000 oersteds. Intrinsic Induction at each magnetizing force is equal to $24.6\ F/AH^2$, where F is the force in mg acting on the specimen due to the magnetizing current, A is cross-sectional area of the specimen in sq cm, and H is the magnetizing force in oersteds.

Permittivity, Relative

An alternate term for DIELECTRIC Constant.

Phase Angle

The angle by which voltage leads current in a material subjected to an a.c. current. The angle between a material's parallel reactance and its total parallel impedance in a vector diagram when the material is used as the dielectric in a capacitor. Complement of a material's LOSS Angle.

Phase Defect Angle

An alternate term for LOSS Angle.

Porosity

The relative extent or volume of open pores in a material. The ratio of pore volume to overall volume of a material in %. See also Apparent POROSITY.

Porosity of sintered metal powder parts (D328-58T) is determined by measuring the weight of a specimen that is oil-free, again when it is oil-impregnated, and finally when the oil-impregnated specimen is suspended in water. The weight of the oil added is given by the difference in the first two weights, and the volume of the oil added—equivalent to pore volume—is found by dividing the oil weight by the Specific GRAVITY of the oil at the test temperature. Assuming a Density for water of 1 gm per cu cm, total volume of the specimen is equal to the loss in weight of the oil-impregnated specimen in water.

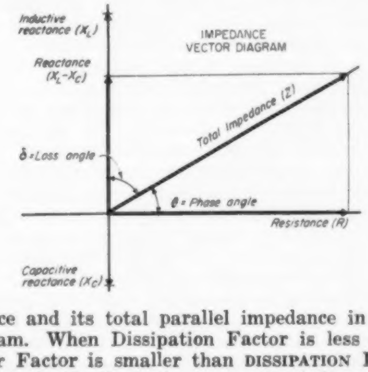
Three methods are used for electrical porcelain (D116-44). In testing porcelain it is important that a certain amount of newly fractured surface be present. Where water absorption exceeds 0.1%, Porosity is reported in terms of water absorption, determined by weighing before and after 30-min submersion in boiling water, followed by quenching and wiping (Method A). In Method B, the volume of air contained in the pores is determined. The McLeod Porosimeter is often used. The fractured specimen is placed in a receptacle where it is exposed to a vacuum for at least 1 min. The air in the pores expands into the evacuated space around and above the porcelain and is collected in a capillary tube, adjusted to atmospheric pressure by a mercury leveling procedure, and pore volume read. Total volume may be determined by a method similar to that for metal powder parts (above), using water impregnation. In Method C, Porosity is indicated qualitatively by the penetration of a dye into the porcelain. Freshly broken ¼ to ¾-in. fragments are immersed in a fuchsine solution under 4000 psi for 15 hr or 10,000 psi for 5 hr, then dried and broken open.

Porosity, Apparent

The POROSITY of a material based on volume is calculated from exterior measurements. Typical is the test used for fired whitewares (C373-56) and burned refractory brick (C20-46). The exterior volume of the specimen in cu cm is calculated from dimensional measurements, and its dry weight in gm determined. Then the specimen is saturated by boiling 5 hr and soaking 24 hr in water, blotted off and weighed again. Assuming the Density of water to be 1 gm per cu cm, the increase in weight in gm is numerically equivalent to open pore volume in cu cm, and Apparent Porosity in % is equal to the difference in weight divided by the calculated volume and multiplied by 100.

Power Factor

A measure of the electrical power loss in a capacitor material subjected to an a.c. field. The ratio of the energy lost in the form of heat to the energy required to charge the capacitor. The cosine of the PHASE Angle ($\cos \theta$) and the sine of the LOSS Angle ($\sin \delta$), and thus the ratio between a material's parallel re-



actance and its total parallel impedance in a vector diagram. When Dissipation Factor is less than 0.1, Power Factor is smaller than DISSIPATION Factor by less than 0.5%. Since the two angles indicated—Phase Angle and Loss Angle—are complementary, the exact relationship between Power Factor and Dissipation Factor can be found by using simple equations or trigonometric tables. Since energy loss is directly proportional to frequency, a low Power Factor is essential in materials to be used at high frequencies.

Quality Factor

The reciprocal of DISSIPATION Factor or Loss Tangent. Also called Storage Factor. When materials have ap-

proximately the same DIELECTRIC Constant, a higher Quality Factor indicates less power loss.

Reactive Power, Specific

For a specified Normal INDUCTION in a material, the component of the applied a.c. power which is "reactive," i.e., returned to the source, when polarity is reversed. The product of induced voltage and the reactive current per unit weight of material, i.e., the product of voltage, current and the sine of the PHASE Angle. It can be determined by the test used for Effective A.C. PERMEABILITY (A346-58). Reactive Power (P_q) of a core is given by an equation in which it is proportional to the square of the equivalent induced voltage (i.e., the measured secondary voltage referred to the primary winding) and inversely proportional to both frequency and the effective parallel inductance of the core as indicated by the value of the variable condenser needed to balance the bridge. Specific Reactive Power in vars per lb is calculated by dividing by the weight of the core. Reactive Power can also be determined by the test used for Incremental REACTIVE Power by simply not energizing the d.c. winding. See also Incremental A.C. PERMEABILITY.

Reactive Power, Specific Incremental

The Specific REACTIVE Power in a magnetic material when subjected simultaneously to a unidirectional ("biasing") and an alternating magnetizing force. It can be determined by the tests used for Incremental A.C. PERMEABILITY (A343-54). In the bridge method, Incremental Reactive Power is calculated from an equation in which it it proportional to frequency and inversely proportional to the value of the variable resistor needed to balance the bridge. In the potentiometer method, Incremental Reactive Power is equal to the product of the indicated quadrature current and the equivalent induced voltage (i.e., the measured secondary voltage referred to the primary winding). Specific Incremental Reactive Power is equal to Incremental Reactive Power divided by the weight of the core. Specific Reactive Power can also be determined by these methods by not using the d.c. winding.

Reflectance, Infrared

A measure of infrared BRIGHTNESS. Two direct optical methods are used. In each, a standard beam of light is thrown on the specimen normal to its surface and reflectance measured from the same position, using filters to select specified wavelengths for viewing in the infrared range. Both illuminating and viewing are diffuse. In one method (Fed 141-6241) a spectrophotometer is used to determine reflectance at each of 30 selected wavelengths. Infrared Brightness may be reported as the average of the reflectance at the 30 wavelengths and at a selected 10 of the 30 wavelengths, or as a Spectral REFLECTANCE curve. In the other method (Fed 141-6242), the Hunter Multipurpose Reflectometer is used to compare the reflectance of the specimen with that of calibrated standards.

A third method—primarily an acceptance test—uses photography (Fed 141-6243). The specimen is photographed simultaneously with calibrated standards representing minimum and maximum acceptable infrared Brightness, using a tungsten lamp, Wratten 89-A filter and infrared film. Direction of illumination is approximately 45 deg to the normal. The developed negative is examined on a light box, using a diffuse light source under frosted or opal glass. The specimen is satisfactory if the density of its image is equal to or greater than that of the minimum reflectance standard. A densitometer, i.e., an instrument that measures quantitatively the relative light transmission through a photographic film, is used where necessary.

Reflectance, Luminous

A measure of the Brightness of a material. The ratio of light reflected by a specimen to the light incident on it. The Luminous Reflectance of a material of such thickness that any increase in thickness would fail to change the value is called Luminous Reflectivity. Calculated from Spectral Reflectance (including the specular component) and spectral luminosity (see COLOR), it is a function of the spectral and angular distribution of incident light energy. Also called Total Luminous Reflectance to more readily distinguish it from Luminous Directional REFLECTANCE.

Reflectance, Luminous Directional

A measure of the Brightness of a material. The ratio of the Brightness of a material to the Brightness that an ideally diffusing, completely reflecting light surface would have when illuminated and viewed in the same manner. The Luminous REFLECTANCE which a perfectly diffusing surface would need in order to appear as bright as the material under test when illuminated and viewed the same way. It depends upon the spectral and angular distribution of incident energy and upon direction of viewing. The term Luminous Directional Reflectivity is used to indicate an inherent property of the material as opposed to that of a particular object.

Luminous Directional Reflectance can be calculated from the Spectral Reflectance curve (see COLOR) excluding the specular or normal component. Where the specular component of reflectance has not been eliminated in the test, it can be eliminated mathematically from the curve by calculating Specular Reflectance for normal incidence (R_1) from Fresnel's equation using Index of REFRACTION of the specimen (n):

$$R_1 = (n-1)^2/(n+1)^2$$

and subtracting it from measured reflectance at each wavelength.

Luminous Directional Reflectance is commonly determined for an opaque material illuminated at 45 deg and viewed normal to the surface. Illuminant C (average daylight) is used to determine daylight Luminous Directional Reflectance of paints, opaque white porcelain enamels and whiteware ceramics, reflectance being viewed by a receptor simulating the normal human eye (CIE standard observer). A blue light is used to determine the Blue Light Reflectance or Brightness of uncolored papers and pulps in sheet form, reflectance being viewed by a receptor having a response equivalent to the z function of the CIE standard observer (E97-55). In each case a photometer reading is taken of the reflectance from the test material and from a standard (magnesium oxide or a "working" standard calibrated against magnesium oxide as 100), and the ratio of specimen to standard calculated. Luminous Directional Reflectance is equal to the assigned reflectance of the working standard multiplied by the calculated ratio and expressed in %. When the green filter is used it is reported as 45-deg, 0-deg daylight Luminous Directional Reflectance. When the blue (or amber) filter is used, it is reported as 45-deg, 0-deg Directional Reflectance for Blue Light (or Amber Light).

Reflectance, Spectral

A measure of Brightness. The ratio of the light reflected by a specimen to the homogeneous light energy incident on it. It depends on angular distribution of the incident energy. The term Spectral Reflectivity is used to indicate the inherent property of a material of such thickness that any increase in thickness would fail to change the Spectral Reflectance. See also Spectral Directional REFLECTANCE. It may be expressed in the form of a curve of Luminous Directional REFLECTANCE vs wavelength. A curve over the wavelength range of 400 to 700 mμ is specified for Spectral Reflectivity of paper (TAPPI T442m-47).

Reflectance, Spectral Directional

A measure of the Brightness of a material. The Spectral REFLECTANCE which an ideal diffusing surface

would need in order to appear the same as the specimen under test when illuminated and viewed the same way. It depends upon the angular distribution of the incident light and upon direction of viewing. The term Spectral Directional Reflectivity is used to denote an inherent property of the material as opposed to that of a particular object.

Reflective Diffusion Value

See DIFFUSION Value.

Reflectivity, Apparent

A term used for the Luminous Directional REFLECTANCE (Reflectivity) of paper (TAPPI T442m-47).

Refraction, Index of

Also called Refractive Index. The ratio of the velocity of light in a vacuum to its velocity in the material. The ratio of the sine of the angle of incidence of light to the sine of the angle of refraction.

For transparent plastics, two methods (D542-50) are used. In the refractometric method, a small drop of contacting liquid having a higher Index of Refraction than the plastic is placed on a ¼ by ½-in., perfectly plane, polished specimen, and that face of the specimen placed against the fixed half of the prism of of an Abbé Refractometer with a polished edge toward the light source. The refractometer is adjusted to provide a half-dark, colorless field such that the dividing line between the light and dark portions of the field as seen through the eyepiece coincides with the intersection of the eyepiece crosshairs, and Index of Refraction for the sodium D line is read directly from the instrument. A similar test is used in estimating changes in composition occurring in askarels (D901-56); the oil is placed directly on the prism.

In the microscopic method, a plane specimen is placed on the stage of a microscope with the polished surface nearest to the objective lens. The microscope is focused on the bottom surface as seen through the material, then on the top surface, and the microscope displacement noted. Index of Refraction is equal to the actual thickness of the material divided by its apparent thickness as measured by the microscope displacement. Whereas the refractometric method is accurate to four significant figures (provided wavelength of light is specified), the microscopic method is accurate to only three.

Reluctivity

The reciprocal of the magnetic Normal PERMEABILITY of a material (v).

Resistance, Insulation

A measure of the ability of a nonconducting material to resist flow of an electric current. The ratio of 1) the direct voltage applied between two electrodes in contact with the material, to 2) the total current between the electrodes, in ohms or megohms. Since this test permits current to flow both through the specimen and along its surface, Insulation Resistance does not differentiate between Volume RESISTIVITY and Surface RESISTIVITY. It is a property of the form, not the material, and thus useful only in comparing materials having the same form. It is sometimes used as a convenient method of classifying dielectrics of given form, e.g., laminated thermosetting plastics sheet (D229-58).

The specimen—generally in the form of flat plate, tape or tube—is connected to form part of an electrical circuit. Electrodes may be embedded or simply in contact with the material. They may consist of binding posts of various types to simulate expected service conditions, or of various conductive surfaces such as metal strips, silver conductive paint, sprayed or evaporated metal, lead or tin foil, mercury confined by a ring, colloidal graphite dispersion, or highly conductive rubber. An example of the use of binding post electrodes is D700-57T for phenolic molding compounds. The posts are inserted in holes drilled in a compression molded disk ⅛ in. thick and 4 in. in dia—one in the center and six others equally spaced around a concentric circle. Measurements are made between the center electrode and each of the other posts. An example of the use of metal strips is D1202-52T for cellulose acetate sheet and film. Two bright brass strips ¼ in. square and at least 1¼ in. long are placed one on each side of the specimen.

Voltages of 100 or 500 v are most commonly used, but higher voltages up to 15,000 v may be used to increase sensitivity or where information on voltage-resistance characteristics is desired. Since both volume and surface resistance may be voltage-sensitive, comparisons between materials can be made only where they have been tested under the same voltage—and sometimes (e.g., in testing cable) the same polarity.

Resistance is measured after current has dropped to the extent that its further decrease is asymtotic with time. For some materials and electrodes the correct time of electrification must be determined by making preliminary resistance-time measurements and plotting a curve, but ordinarily an electrification time of 1 min is specified. Resistance is measured in two ways. In one method, the voltage and current in the external circuit are measured directly and resistance is either computed or indicated directly by an instrument. Greater sensitivity—though sometimes less precision—can be obtained by electrically amplifying the voltage drop by a known amount before measuring. In the other method, the same test voltage is applied to a material of known resistance, and resistance of the specimen is determined either by measuring and comparing the two resulting currents or by balancing the two resistances in a bridge circuit. Results are not usually reproducible closer than 10% and may diverge much more.

Since Insulation Resistance of a solid dielectric decreases exponentially with increasing temperature and increasing humidity, it is essential to measure resistance under specified, controlled conditions (it is reported that a change from 90 to 95% RH can change Insulation Resistance by a factor of 1,000,000). Additional error can result from peculiarities of the measuring circuit if precautions are not taken.

Electrical insulating oils of the petroleum type (D1169-58) and solid filling and treating compounds (D176-56T) are tested in a cell at voltages ranging from 3 to 30 v per mil. Insulation Resistivity of insulating oils can be calculated by applying the correct factor for the cell; formulas for plate, cylindrical and nonsymmetrical electrodes are given in D1169-58.

A special method is used for nonrigid vinyl tubing (D876-58T). A 2-ft specimen is bent to a U-form, immersed 1 ft deep in a 1% salt solution with both open ends protruding, and filled with the same salt solution. The two bodies of salt water are used as the electrodes. Insulation Resistance is determined after 24-hr immersion and is reported as megohms per ft. Sometimes this value is converted to Volume Resistivity.

Resistivity, Electrical

The electrical resistance of a material (usually a metal) 1) per unit length and unit cross-sectional area (see RESISTIVITY), or 2) per unit length and unit weight (see Weight RESISTIVITY). See also Volume RESISTIVITY and Surface RESISTIVITY for dielectrics.

Resistivity

The ability of a material to resist the flow of an electric current. Generally, the electrical resistance of a material per unit length and unit cross-sectional area. Also, the electrical resistance of a material per unit length and unit weight (see Weight RESISTIVITY). A term generally reserved for metallic materials, where the distinction between the two components, Volume RESISTIVITY and Surface RESIS-

TIVITY, is not usually made as it is for dielectric materials. A voltage is applied across the conductor and its electric resistance measured, usually by balancing a bridge circuit. Resistivity in microhm-cm or ohm-cir mil/ft is equal to 10^6 AR/L where A is the cross-sectional area of the electrical path in sq cm or cir mils, R is the measured resistance in microhms or ohms, and L is the gage length (length of the electrical path) in cm or ft. For electrical conductor materials, the specimen (D193-58) is at least 1 ft long and may be wire, strip, rod, bar, tube or other shape of uniform cross section. For materials used in resistors, heating elements and electrical contacts (D63-49), the specimen may be wire or strip at least 1 ft long, or, in the case of nonductile materials, a special 3-in. long shape having square ends but a cylindrical center section. For magnetic materials (A344-52), the specimen is a straight bar or strip 10 in. or longer. In this case, cross-sectional area A is determined by dividing weight by density and length. Resistivity of flat rolled magnetic materials is measured parallel to the direction of rolling. For conductors the terms Resistivity and Volume Resistivity are used interchangeably. Resistivity is more common for metals; on the other hand, Volume Resistivity is used for electrically conductive rubber.

Resistance, Interlamination

A measure of the resistance of a laminated magnetic structure to stray, intersheet power losses (A344-52). Generally a measure of the effectiveness of sheet surface oxides or coatings in reducing intersheet losses.

In Method 1, 40 small Epstein strips (about 10 by 1³⁄₁₆ in.) of the magnetic material, freed of burrs and loose particles, are stacked up on a copper plate backed by an insulating block. Another copper plate and insulating block are placed on top and a preload of 500 psi applied. One copper plate is connected to a potential circuit, the other to a current-indicating circuit. Additional test pressures of 100, 200, 500 or 1000 psi are applied and stack resistance in ohms determined by Ohm's Law from voltage and current measurements. Interlamination Resistance per strip in ohm-sq cm is calculated by multiplying stack resistance by cross-sectional area (i.e., the area of a strip) and dividing by the number of strips.

Method 2 is primarily a quality control test for strip or punchings of flat rolled electrical steel. A strip is placed on a hot plate, heated to a specified temperature, and a specified pressure applied by a test head having 10 contacts, each in series with a resistor. A voltage is applied across the plate and test head, and current through each contact circuit measured by moving an ammeter lead from one contact to another, thus giving 10 measurements. Voltage is adjusted so that the ammeter reading ranges from 0 amp for a perfect conductor to 1 amp for a perfect insulator. Interlamination Resistance per lamination is calculated by subtracting one (1) from the reciprocal of the ammeter reading and multiplying the result by a constant. This formula is derived from Ohm's Law as modified for parallel resistances, the parallel resistances being the series resistance connected to the contact and the resistance of the coating between the contact surface and the lamination.

Resistivity, Insulation

A measure of the ability of a material to resist the flow of an electric current. Insulation RESISTANCE per unit volume. This property makes no distinction between Volume RESISTIVITY and Surface RESISTIVITY. Even where no such distinction is made in the test, however, it is more common to use the term Volume Resistivity.

Resistivity, Surface

A measure of the ability of the surface of a dielectric material to resist the flow of an electric current. The ratio of 1) the potential gradient parallel to the current along the surface of a material, to 2) the current per unit width of surface. Surface Resistivity is numerically equal to the Surface Resistance between two electrodes forming opposite sides of a square, regardless of the size of the square. In general, Surface Resistivity of dielectrics is equal to PR_s/g, where R_s is Surface Resistance in ohms, g is the distance in cm between electrodes, and P is the effective "parameter" of the guarded electrode. Various formulas are given in D257-58 for calculating the effective parameters for rectangular, circular and tubular electrodes. Formulas are also available for correcting these parameters to compensate for current "fringing" at electrode edges or lack of uniform current density between electrodes.

In determining Surface Resistance (D257-58), the specimen is generally in the form of flat plate, tape or tube. A known voltage is applied between two electrodes in contact with the same side of the material. A third electrode in contact with the opposite surface draws off current that passes through the volume of the material. The resistance measured in this method is actually the resultant of two parallel resistances—the Volume Resistance and the Surface Resistance. However, the electrodes are dimensioned in such a way that the effect of the Volume Resistance is negligible. Electrodes vary considerably, depending on the form of the material. For sheet and plate, the test electrodes usually consist of two concentric rings. For tube, the test electrodes consist of a broad band encircling the specimen and a narrow band at each end, and the guard electrode covers the inside surface. The gap between test electrodes is about twice the thickness of the material. Voltage is applied and resistance measured as in the Insulation RESISTANCE test.

Although Surface Resistivity is of some interest in itself, knowledge of its changes with temperature and humidity is even more important, and curves plotted against these variables are usually desirable. Variations in humidity, particularly, have a great effect on Surface Resistivity; under high humidity conditions, dielectrics tend to develop a surface layer of moisture which is a good conductor. Together with Volume RESISTIVITY, Surface Resistivity is often used in checking the purity of an insulating material during development and its uniformity during processing.

Resistivity, Volume

A measure of the ability of a material to resist the flow of an electric current. The ratio of 1) the electrical potential gradient parallel to the current in a material, to 2) the current density. In the metric system, Volume Resistivity in ohm-cm is numerically equal to the Volume Resistance between opposite surfaces of a 1-cm cube of the material. In general, Volume Resistivity of dielectrics is equal to AR_v/t, where A is the effective area of the guarded electrode in sq cm, t is the thickness of the specimen in cm, and R_v is the measured Volume Resistance in ohms. Various formulas are given in D257-57T for calculating the effective areas of circular, rectangular and special-shaped electrodes. Formulas are also available to compensate for differences between calculated area and true area resulting from "fringing" at electrode edges or lack of parallelism between electrode surfaces. In the case of liquid insulating materials where Volume Resistance is measured in a cell, Volume Resistivity may be determined by simply multiplying measured resistance by a cell constant which is proportional to the Capacitance of the electrode system with air as the dielectric.

In determining Volume Resistance, the specimen (D257-57T) is generally in the form of flat plate, tape or tube. A known voltage is applied between two electrodes, one in contact with each side of the specimen. A third electrode in contact with one side of

the specimen draws off surface current leakage; the "guard" electrode or ring is sometimes omitted with dry materials having negligible surface leakage, in which case Insulation RESISTANCE is the property actually determined. Electrodes vary considerably, depending on the form of the material. For sheet and plate, the guarded electrode and its guard consist of two concentric rings. For tube, one electrode covers the inside surface, another covers part of the outside surface, and the guard consists of two encircling rings—one at each end. The gap between the guarded and the guard electrodes is kept as small as possible. Diameter or shortest side of an electrode is at least four times the thickness of the specimen. Voltage is applied and resistance measured as in the Insulation Resistance test.

Volume Resistivity of electrically conductive rubber (D991-48T) is calculated directly from voltage and current measurements. Current is passed parallel to the calender grain of a 6 by 6-in. slab and voltage and current measured by a galvanometer and null balance circuit. A formula analogous to the one above is used, R being replaced by the ratio of voltage to current and t by the width of material between the electrodes. Volume Resistivity of metallic conductors (D193-58) is also calculated by an analogous formula. However, the simpler term RESISTIVITY is somewhat more common for metallic conductors.

Although Volume Resistivity is of some interest in itself, knowledge of its changes with temperature and humidity is even more important, and curves plotted against temperature, particularly, are sometimes desirable. In addition, in the case of solid dielectrics, it is sometimes possible to develop correlations with such properties as Dielectric Strength and Dissipation Factor, and such factors as moisture content, degree of cure, mechanical continuity and deterioration. Thus Volume Resistivity can serve as a relatively easily measured index to detect changes in even more significant properties during development and processing.

Resistivity, Weight

A measure of the ability of a material to resist the flow of an electric current. Also called Mass Resistivity. The electrical resistance of a material per unit length and unit weight. A term generally reserved for metallic materials, i.e., conductors. Weight Resistivity in ohm-lb/sq mile or ohm-gm/sq m is equal to $WR/L_1 L_2$ where W is weight of specimen in lb or gm, R is measured resistance in ohms (see RESISTIVITY), L_1 is the gage length in miles or m used to determine R, and L_2 is the length of the specimen.

Retentivity

The maximum value of Residual INDUCTION in a magnetic material (B_{rs}). A measure of the permanence of magnetization in a material. Low values are desirable for electromagnetic devices, high values for permanent magnets, relays and magnetos.

Saturation

The attribute of any color having a HUE which determines the extent to which it differs from a gray of the same LIGHTNESS.

Scatter, Coefficient of

For white porcelain enamels (C347-57), the rate at which reflectance increases with thickness as thickness approaches zero over an ideally black backing.

Six or seven panels are prepared having coatings of different thicknesses calculated to give reflectances ranging from 50 to 75%. Weights of dry process enamels are determined as applied; weights of wet process enamels after drying and before firing. Coating thickness is expressed in terms of weight per unit area. After firing, the 45-deg, 0-deg Directional REFLECTANCE of each panel is determined. A photometer or reflectometer is used to illuminate the specimen at an angle of about 45 deg and view it at an angle of about 15 deg from the normal. The illuminant is the standard for average daylight (C) and the receptor is the CIE standard for the normal human eye. Next, the Luminous Directional REFLECTANCE (Reflectivity) of the coating is determined by measuring the reflectance of a coating having four times the weight required to obtain 75% reflectance. From a chart based on a formula developed by Kubelka and Monk, the value of Luminous Directional Reflectivity and the individual values of reflectance for the coatings can be used to determine the individual scatter-thickness products for each coating. Individual values of scatter are calculated by dividing each product by corresponding coating weight, and the results averaged to give Coefficient of Scatter.

Shade

A term used to characterize the difference in LIGHTNESS between two surface colors, the other attributes of COLOR being essentially constant. A lighter shade of a color has higher lightness but about the same HUE and SATURATION.

Sheen

The 85-deg Specular GLOSS of nonmetallic materials.

Softening Point

An indication of the maximum temperature to which a nonmetallic material can be heated without loss of its normal "body." The minimum temperature at which a specified deformation occurs under a specified load. Softening Point is often determined for materials that have no definite MELTING Point, i.e., materials that gradually change from brittle or very thick and slow flowing materials to softer materials or less viscous liquids.

Vicat Softening Point (D1525-58T) is commonly determined for polyethylenes, and may be determined for polystyrenes, acrylics and cellulose acetate. The test is unsuitable for some thermoplastics because of their wide Vicat softening range. A flat specimen ⅛ in. thick is cut from compression molded sheet, placed in a temperature bath and subjected to a 1000-gm load by a flat-ended needle having a 1-sq mm circular or square cross section. Temperature is raised 122 °F per hr and the temperature noted at which penetration is 1 mm.

For hard rubber (Fed 601-11311), a strip 5 by 1½ by 3/16 in. is supported at the ends in a temperature bath, a 5.5-lb load applied at the center of the span, temperature raised 3.6 °F per min, and temperature recorded for each 0.015-in. deflection, as shown by a dial indicator. Deflection is plotted against temperature, a curve drawn, and a tangent constructed to the linear portion of the curve. Softening Point is the temperature at which the tangent intersects the temperature axis.

The ring and ball test (E28-58T) also measures the deflection of a span. It is used for asphalts, tars, pitches, resins and the like. The material is poured or molded into a ⅝-in. ring, the leveled-off ring suspended horizontally in a temperature bath, a ⅜-in. steel ball placed on top, and temperature raised 10 °F per min. Softening Point is the temperature at which the material has sagged far enough to touch a plate 1 in. below the ring.

For glass, Softening Point is the temperature at which a uniform fiber 0.55-0.75 mm in dia and about 9 in. long elongates 1 mm per min under its own weight when the upper 100 mm of its length are heated at 9 °F per min. Length is read each half-minute, and temperature (i.e., a potentiometer) each half-minute between length measurements. Difference in length for each half-minute is plotted on a log scale against temperature, a straight line drawn through the points, and the temperature at which the curve intersects the 0.5-mm elongation line noted.

Solidus Temperature

The temperature at which an alloy begins to melt during heating or finishes freezing during cooling. For pure metals, the same as the LIQUIDUS Temperature and known simply as the MELTING Point.

Sound Absorption Coefficient, Normal Incidence

A measure of the effectiveness of a material in absorbing sound energy. The fraction of normally incident sound energy absorbed by a material which is assumed to have an infinite surface. With care, this coefficient can be used to calculate a rough estimate of the Statistical SOUND Absorption Coefficient which applies to the more usual case where sound is reverberant, i.e., impinges at random incidence.

The Normal Incidence Coefficient is determined (C384-56T) by means of a long rigid tube having the specimen mounted in one end and at the other end a speaker and amplifier driven by a source of sinusoidal plane waves. The tube is of uniform round or square cross section. Sound waves of reduced amplitude are reflected by the specimen and combine with the incidence waves to form a standing wave pattern along the tube. This pattern is explored along the axis of the tube by a movable microphone or probe, the output being fed to a decibel indicator. The difference in decibels, L, between the maximum and minimum pressure amplitude of the standing wave ("standing wave ratio") is determined, and normal incidence coefficient calculated as follows:

$$\alpha_n = 1 - \left[\frac{(\log_{10}^{-1}[L/20]) - 1}{(\log_{10}^{-1}[L/20]) + 1}\right]^2$$

Frequencies tested are generally chosen from the series: 125, 250, 500, etc. The coefficient can vary considerably depending on the method of mounting the specimen. This same test is used to determine Specific Normal ACOUSTIC Impedance.

Sound Absorption Coefficient, Statistical

A measure of the effectiveness of a material in absorbing sound energy. The fraction of incident sound energy absorbed by a material under conditions where it is subject to equal sound energy from all directions over a hemisphere, i.e., under reverberant sound conditions. Measurement is expensive and time-consuming, requiring a specially constructed reverberation chamber. As a result, this property is sometimes estimated from Specific Normal SOUND Absorption Coefficient or Specific Normal ACOUSTIC Impedance. The Normal Coefficient is about half the Statistical Coefficient for very low values and approaches equality with it at very high values. The maximum numerical difference occurs at intermediate values and is on the order of 0.25 to 0.35.

Storage Factor

The reciprocal of DISSIPATION Factor or Loss Tangent. Also called QUALITY Factor.

Surface Irregularities

A test for flat transparent plastics sheets (D637-50) in which the extent of surface irregularities is determined in terms of Displacement Factor, Frequency (and Nature) of Image Shift, and Pattern Distance. The specimen is held about 12 in. in front of the lens of a projector with its plane perpendicular to the direction of projection. The sheet is moved about so that its entire area, except the border, is surveyed by the beam of light. During this movement, a ruled screen about 25 ft away is observed to check on the movement of the projected image of a cross.

Frequency of Image Shift is reported as 1) irregular or wavy, 2) frequent, or 3) single shift. The maximum image movement in in. is noted, and maximum Displacement Factor calculated by dividing the distance in ft from the projector to the screen and multiplying by 100.

To measure Pattern Distance, the specimen is held 5 in. from the screen and moved back and forth parallel to the screen, the screen being observed for any projected images of minor irregularities. Distance from the screen is increased in increments of 5 in. until a pattern is observed. Pattern Distance is the maximum distance in integer multiples of 5 in. that the sheet can be held from the screen without producing a pattern of its minor irregularities.

This test is useful in evaluating the quality of sheets used to cover openings through which visual and instrumental observations are to be made; it does not measure microscopic defects or optical perfection of surfaces in terms of wavelengths of light.

Temperature-Resistance

The relationship between a material's temperature and its electrical resistance, expressed by a multivalue table, by a graph, by a calculated temperature coefficient, or by the calculated values for the constants in a standard mathematical equation. It provides information needed for design and use of 1) resistance heating elements, and 2) precision resistors in electrical and electronic circuits.

For resistance heating alloys (B70-56), a specimen is subjected to a low current and is heated in a furnace to equilibrium at the highest test temperature. Then temperature is lowered in steps of about 212 °F, resistance being measured by applying an electrical potential and balancing a bridge circuit. Results are plotted as a curve of temperature vs resistance.

For wire used in resistors (B84-52) and sheet used in resistor shunts (B114-45), a current is passed through the specimen while it is submerged in an oil bath. An electrical potential is applied to the specimen and resistance is measured first at room temperature, then at the highest test temperature, and finally at several intermediate temperatures in decreasing order. Maximum temperature range covered by this test is about 32 to 170 F. Wire specimens are wound in a circular coil about 2 in. in dia, an insulating form being used for wire not insulated. Temperature-Resistance can be defined by the values for the three constants, R_{25} (resistance at 25 C), α and β in the following equation: $R_t = R_{25} [1 + \alpha (t - 25) + \beta (t - 25)^2]$. These constants may be found by selecting three temperatures (t) and the corresponding resistance (R_t) values from the test and substituting them in the basic equation to form three equations that can be solved simultaneously. This procedure can be simplified by proper choice of temperatures. In addition to the constants, results of this test should include the temperature at which change in resistance with temperature is zero, if it is within the test range. For alloys having high specific resistance and low change in resistance with temperature over the —80 to 480 F range, results are preferably reported not in terms of the basic equation but in terms of a simple temperature coefficient based on a two-step test and equivalent to $(R_2 - R_1)/(T_2 - T_1)$; T_1 and T_2 are the lower and higher temperatures, and R_1 and R_2 are the resistances at the lower and higher temperatures, respectively. For sheet used in resistor shunts, test data are sometimes simply plotted as a curve with temperature as abscissa vs % or ppm change in resistance.

Thermal Diffusivity

The rate at which temperature diffuses through a material. The ratio of Thermal CONDUCTIVITY to the product of DENSITY and Specific HEAT, commonly expressed in sq ft per hr.

Thermal Expansion, Cubical Coefficient of

The rate at which a material increases in volume when heated. The unit increase in volume of a mate-

rial per unit rise in temperature over a specified temperature range. The slope of the temperature-volume expansion curve at a specified temperature. The Mean Coefficient is the mean slope of this curve over a specified range of temperature. See also THERMAL Coefficient of Linear Expansion.

For plastics (D864-52) care is necessary to exclude as much as possible the effects of moisture content, curing, loss of plasticizer or solvent, stress release, etc. The specimen is a rod about 6 by ¼ by ¼ in. Its weight and volume (V_s) are measured; then it is placed in a bulb at the lower end of a narrow tube, and the weight of the assembly measured. The tube is then filled with mercury to a marked level and weighed again to determine the weight of mercury added (its volume is determined from its Specific Gravity). The assembly is immersed in a bath to a marked depth and heated, the mercury reading being plotted against temperature. Readings may be made at equilibrium in 9 or 18 °F increments, or at 9 °F intervals while raising temperature steadily at 0.9 °F per min. The curve generally has two straight-line portions which intersect at the transition point; the slope of each curve is determined. Total mercury expansion per °F (ΔV_t) is equal to the rise-temperature change slope multiplied by the cross-sectional area of the tube. Internal volume of that portion of the tube immersed in the hot bath is found by adding the original mercury volume to the volume of the specimen. The volume expansion of mercury per °F that can be attributed to mercury alone (V_m) is equal to the volume expansion assuming only mercury (i.e., internal volume multiplied by the difference in the cubical coefficients of mercury and the glass) minus the volume expansion of mercury per °F equivalent to the volume of the specimen (V_s times the cubical coefficient of mercury). Thus, the volume expansion per unit volume of the specimen per °F is equal to $(\Delta V_t - V_m)/V_s$. The Coefficient for plastics is commonly given at −22 and 86 F.

For solid filling and treating compounds used for electrical insulation (D176-56T) either a True (gas-free) or Effective (not degassed) Coefficient may be determined. In general, the coefficient may be determined simply by measuring the expansion in volume per unit volume that occurs between two equilibrium temperatures, and dividing by the temperature difference. A correction for the cubical expansion of the container is often necessary. The coefficient is usually determined for three temperature ranges: from lowest temperature measured to 18 °F below SOFTENING Point (average coefficient for solid condition); from 9 °F above Softening Point to 90 °F above Softening Point (average coefficient for liquid condition); and from lowest temperature measured to 90 °F above Softening Point (overall coefficient).

Several methods are used. In Method A, a precise test for low viscosity compounds such as waxes and petrolatums, the compound is heated in a volumetric flask and the increase in volume noted at various temperatures. A temperature-expansion curve is plotted, and True or Effective Coefficient calculated at any temperature by dividing the difference in volume by the original volume and the temperature difference. In Method B, used for asphalt and other high viscosity materials as well as opaque materials, a 250-ml cell is calibrated in volume vs temperature, the compound is placed in the cell, the cell weighed, mercury added to fill the cell, the specimen degassed, and the cell reweighed to determine the weight of mercury needed to fill it. At each temperature, the amount of mercury extruded out of the cell is weighed and its volume—equivalent to the expansion of the compound—calculated from its Specific Gravity and corrected by the cell calibration curve. This method determines the True Coefficient. Method C is fast but not highly precise. Specific Gravity is determined at two temperatures, and either True or Effective Coefficient calculated by dividing the change in Specific Gravity by the Specific Gravity at the higher temperature and by the temperature difference. In Method E, also fast, the molten compound is poured into a weighed 100-ml pycnometer, and more added as it cools to fill the flask level. The flask is weighed to determine weight of compound. At each temperature, the amount of compound extruded from the flask is weighed. Either True or Effective Coefficient is calculated by dividing loss in weight by the weight at the higher temperature and by the temperature difference.

For hydrocarbon waxes (D1168-58T), the volumetric capacity of a dilatometer is calibrated vs temperature, and the Density of glycerine vs temperature is determined. Several void-free pieces of wax are placed in the dilatometer (their weight determined by weighing before and after), glycerine is added (the amount being determined by weighing before and after), and volume is read at a series of temperatures. At each test temperature, the volume of glycerine can be determined from its mass and its Density at that temperature as previously determined. The volume of the wax is the difference between the volume of the dilatometer, as determined by calibration, and the glycerine volume. Density of the wax at any temperature is calculated by dividing its weight by the volume at that temperature. Densities at various temperatures are converted to Specific Volumes, and mean Cubical Coefficient of Thermal Expansion calculated by dividing the difference in Specific Volume at two temperatures by the difference in temperature. The Cubical Coefficient for the solid state is based on the range from the lowest test temperature to 18 °F below the Melting Point. The Cubical Coefficient for the liquid state is based on the range from 9 °F above the Melting Point to 210 °F or the highest test temperature.

Thermal Expansion, Linear Coefficient of

The rate at which a material elongates when heated. The unit increase in length of a material per unit rise in temperature over a specified temperature range. The slope of the temperature-dilation curve at a specified temperature. The Mean Coefficient is the mean slope between two specified temperatures. See also Cubical Coefficient of THERMAL Expansion.

The Coefficient is usually determined by means of a dilatometer, which consists essentially of a tube in which the specimen is placed, and an inner transmission tube which rides on the free end of the specimen, transmitting its displacement to a dial gage.

Over a range where the coefficient is constant, it may be determined simply by measuring the expansion per unit length that occurs between two equilibrium temperatures, and dividing by the temperature difference. A correction for the dilation of the dilatometer tube is generally necessary. For greater accuracy or where changes in slope occur due to phase changes in the material, a number of readings may be made and temperature-dilation curves plotted. For oxidation resistant alloys at temperatures up to 1900 F (D95-39), it is common to make expansion measurements during both heating and cooling to disclose any lack of reversibility of dilation characteristics and to show the direction and magnitude of any permanent change in length. The specimen is ¼ to 7/16-in. rod 4 in. long. Where information on non-equilibrium dilation characteristics is desired, i.e., dilation for practical heating or cooling rates, cumulative time is also measured and curves of time vs temperature and time vs dilation are plotted, enabling corresponding values of temperature and dilation to be found for each of an arbitrarily chosen series of times. From these coordinated values, practical temperature-dilation curves may be constructed. A similar specimen is used for glass (C337-57), and equilibrium dilation measurements are made at 32 and

572 F. For fired whiteware ceramics (C372-56), a round or square rod with 0.05 to 0.2-sq in. cross section and 2 to 8-in. length is heated at 2 to 5 °F per min, measurements being made at intervals no greater than 90 °F. In determining the Coefficient for plastics (D696-44), care is necessary to exclude as much as possible the effects of moisture content, curing, loss of plasticizer or solvent, stress release, etc. Dilation is measured at −22 F and 86 F and checked by cooling back to −22 F. The same method is used for electrically insulating sheet and plate (D229-58).

An interferometric method is also used for fired whiteware ceramics at temperatures below 1900 F (C327-56). A specimen is arranged as a 3/16-in.-high tripod using either projecting parts of the same material or three separate fragments, the three legs being ground to equal length. The specimen is placed between fused silica interferometer plates in the furnace and heated about 5 °F per min. At each temperature reading, linear thermal expansion in % is equal to $(n\,\lambda/200\,h) + A_e$ where n is the number of fringes passing the reference point during that change in temperature, λ is the wavelength in μ of the light source, h is the starting height of the specimen in cm, and A_e is the air correction between the two temperatures in % (given in a table).

Thermal Resistance

See Thermal TRANSMITTANCE.

Thermoelectric Power

The ability of a metal to develop an electromotive force when in contact with a dissimilar metal and subjected to a thermal gradient. In B77-33, the emf developed by a metal with respect to copper per °C of temperature difference between the junctions. A sheet, ribbon or wire of the metal is soldered, brazed or welded to copper leads at each end, the two junctions held at temperatures differing by at least 35-40 °F (two oil baths are sometimes used), and the generated emf measured by connecting the leads to an appropriate electrical circuit. Thermoelectric power in mv per °F or °C is equal to the emf divided by the temperature difference. Polarity is reported positive if the direction of current flow is from the higher temperature to the lower temperature, negative if the reverse.

Transmissive Diffusion Value

See DIFFUSION Value.

Transmittance, Diffuse

The ratio of light scattered by a material to the light incident on it. The ratio depends on the spectral distribution of the incident energy. See HAZE. The analogous spectral ratio is Diffuse Luminous TRANSMITTANCE.

Transmittance, Diffuse Luminous

The ratio of the light scattered by a material to the light incident on it. For transparent plastics having less than 30% Haze, Diffuse Luminous Transmittance is measured in determining HAZE.

Transmittance, Luminous

The ratio of the light transmitted by a material to the light incident on it. Calculated from spectral transmittance and spectral luminosity (see COLOR), it is a function of the spectral distribution of the incident light energy. In the test for HAZE, it is called Total Luminous Transmittance to distinguish it from its diffuse component, Diffuse Luminous Transmittance.

Transmittance, Thermal

The rate at which heat is transmitted through a material by combined conduction, convention and radiation. The overall coefficient of heat transfer. A term used particularly for textile fabrics and batting where the heat transfer between opposite surfaces is not confined to conduction. For solid materials, Thermal CONDUCTIVITY is a measure of Thermal Transmittance.

Thermal Transmittance is measured by the "guarded hot plate" method (D1518-57T). The specimen is placed on a hot plate which is brought to the specified temperature under a hood. A specified humidity and "low" temperature are maintained above the specimen, a guard ring around the hot plate serving to prevent side flow of heat. After equilibrium, measurements of test plate temperature, test plate heater wattage, and air temperature above the specimen are made at 10-min intervals for 30 min. The test is repeated with the hot plate uncovered. The combined transmittance coefficient of specimen and air in Btu/hr/sq ft/°F is equal to the power loss from the test plate in Btu per hr divided by area of the plate in sq ft and temperature difference in °F between the test plate and the air. The transmittance coefficient of the bare plate is calculated the same way. Effective Insulation Ratio is equal to the bare plate transmittance coefficient divided by the combined coefficient for fabric and air. The reciprocal of the Intrinsic Transmittance Coefficient of the fabric alone is equal to the difference of the reciprocals of the two calculated coefficients; thus Intrinsic Transmittance Coefficient ("U_2" or "C") of the fabric alone is equal to the product of the two coefficients divided by their difference. Intrinsic Transmittance Coefficient is multiplied by fabric thickness in in. to obtain the Specific Conductivity Coefficient (k) or thickness in ft to obtain the Conductivity Coefficient (K); and its reciprocal is Intrinsic Thermal Resistance Coefficient. Intrinsic Thermal Resistance in clos is $1.137/U_2$; Specific Thermal Resistance in clos is 1.137/k.

The method is restricted to materials for which the Intrinsic Transmittance Coefficient lies between 0.125 and 2.5 Btu/hr/sq ft/°F.

Transmittance, Total

The ratio of light transmitted by a material to the light incident on it. The ratio depends on the spectral distribution of the incident light energy. See HAZE. The analogous spectral ratio is Luminous TRANSMITTANCE.

Transmission Factor, Diffuse Light

See DIFFUSE Light Transmission Factor.

Voltage Ratio

An alternate term for Surface BREAKDOWN Ratio.

Volume, Specific

The reciprocal of DENSITY.

Wettability, Surface

A test for the wettability of paper (D724-45). It measures Initial Wettability and Rate of Change in Wettability. A piece of paper ½ by 4 in. is placed on the slide of the stage of a projector. A drop of the liquid is placed on the specimen with a hypodermic, and the image projected on a glass screen on which is clamped a sheet of transparent paper. A horizontal line is drawn on the paper coinciding with the image of the base of the drop, and when the specified time of contact has elapsed, two tangents are quickly drawn to the curve at the two points of contact with the base line. Angle of Contact is the average of the interior angles between the base line and the two tangents. Angle of Contact after 5 sec of contact is known as Initial Wettability. Rate of Change in Wettability in deg per sec is determined by measuring Angle of Contact after 5 and 60 sec and dividing the difference by 55.

first in silicones

Dow Corning

SILICONE NEWS

for design and development engineers · No. 63

ANNOUNCING A NEW SILICONE GEL

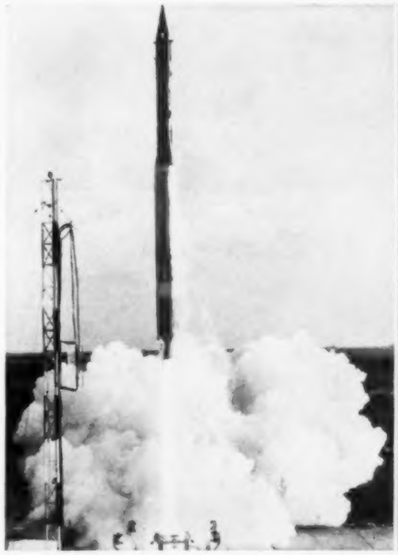
A new silicone, that's supplied in fluid state, can readily be converted to a stable gel. Recently made available by Dow Corning, this new silicone holds much promise as a new engineering material. Typical properties include transparency, heat stability, resiliency, high moisture resistance.

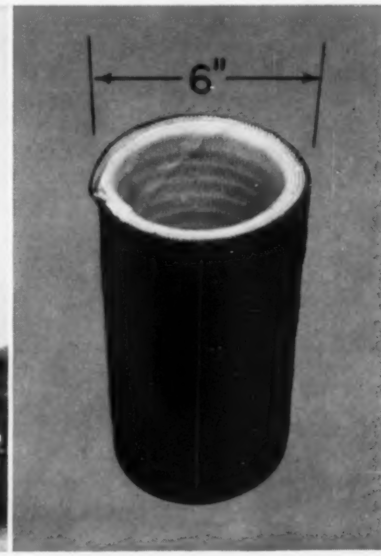
A versatile new silicone, Dow Corning Dielectric Gel has unlimited possibilities for sealing, filling and potting; as a suspension medium; for vibration damping; for impregnating capacitors, magnetic amplifiers and other devices; and a variety of other design possibilities . . . you name the application, and weigh the advantages that this new silicone can provide.

Developed primarily as a potting material for electronic parts, Dielectric Gel has these unique characteristics. Supplied as a water-white fluid with the viscosity of molasses, it pours easily and flows readily around the most intricate parts. It sets up in 48 hours, or can be gelled in 30 minutes with moderate heating. The result is a transparent, resilient gel with good dielectric strength, high moisture resistance

and excellent thermal stability. Subsequent heating will not liquify the gel. Like other silicone fluids and compounds, Dielectric Gel retains its physical and dielectric properties over a wide operating temperature span.

Used as a dielectric for filling and potting electrical and electronic assemblies, the gel's unusual transparency allows visual checks of a potted circuitry, (*Cont. pg. 2*)





TAMING "HOT" MISSILE FUEL

One of the challenges facing designers of missile launching equipment is the development of practical ways to handle "hot" fuels and oxidizers such as 90% concentrated hydrogen peroxide. Here's how Silastic®, the Dow Corning silicone rubber, helped solve this problem:

In its concentrated form, hydrogen peroxide is one of the powerful chemicals developed for oxidation or direct propulsion of rockets and missiles. This chemical reacts so violently in contact with organic materials, however, that finding a suitable means of transferring it from aluminum or ceramic storage tanks to missiles on their launching pads posed a stubborn problem. The concentrated peroxide decomposed so rapidly in contact with conventional flexible hose that it generated explosive forces equal to $\frac{2}{3}$ an equivalent amount of nitroglycerine.

Hewitt-Robins, Stamford, Conn., solved the problem with hose made of Silastic, the Dow Corning silicone rubber. Silastic makes it possible to transfer and handle the peroxide fuel without contamination or change of concentration. Hewitt-Robins combines the desirable properties of Dacron fabric and Silastic by selectively fabricating these two materials in a highly flexible hose having a burst strength exceeding 600 pounds. The hose is fabricated in diameters up to 6 inches and in lengths up to 50 feet. Easy to handle, reel, and store, this hose is currently used by the Navy, Army, and Air Force, for handling and transferring concentrated peroxide liquid propellants.

The section of hose shown is 6" ID heavy duty suction and discharge type believed to be the largest silicone rubber hose built, capable of 600 psi burst and more than 20,000 pounds tension.

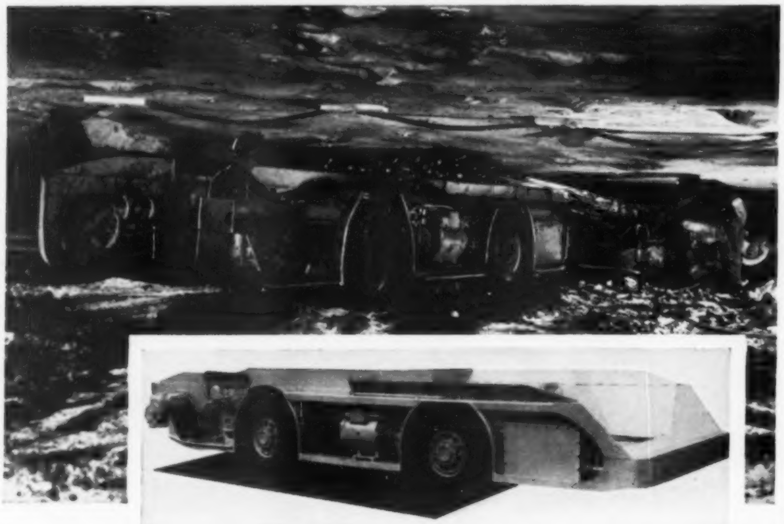
Silastic offers other desirable properties that make it practical under adverse conditions. One example, Silastic can withstand long term exposure to temperatures as high as 500 F and remains serviceable at temperatures as low as —130F. ***No. 643***

TAPES THAT STICK

Dow Corning silicone pressure sensitive adhesives make tapes stick to anything. They achieve a strong, long lasting grip and maintain the desirable properties that characterize silicones — serviceability over a wide range of temperatures; resistance to oxidation, weathering, corrosive chemicals; water repellency; and retention of good dielectric properties. For complete design data on the unique insulating, bonding and sealing abilities of tapes made with Dow Corning silicone adhesives, and their applications, circle .... ***No. 644***

FOR DATA RELATING TO THESE ARTICLES, CIRCLE REFERENCE NUMBER IN COUPON ON NEXT PAGE

MORE



REDUCE DOWNTIME IN THE PITS

Silicone insulated drive motors keep production moving even under the adverse operating conditions found in coal mines. Proof is the exceptional reliability of silicone insulated electrical mining machinery produced by Goodman Manufacturing Co., Chicago.

Best way to design for reduced downtime, Goodman engineers have found, is to insulate electrical drive motors for their mining equipment with Dow Corning Silicones. Used in coal, gypsum, potash, and other mining operations, Goodman equipment is powered with silicone insulated motors to assure the extra overload capacity needed for long life . . . dependable, easy, safe operation.

Take their new four-wheel drive "584" shuttle car, for example. It's powered by 440 volt, 3 phase, 60-cycle current through a cable reel to 20-hp traction motors located between the wheels on each side. Each of the two motors drives a front and rear wheel through drive shafts, a gear reducer and differential.

At high speed, the motors operate at 1750 rpm and are rated 75 C rise at full load . . . at low speed, motor rpm is 875, temperature rise, 120 C. Silicone insulation permits efficient operation of these permissible type a-c traction motors at overloads that push motor temperatures above rated Centigrade rise. Variations in car speed are obtained without electrically controlled clutches and torque converters.

Designed for continuous, uninterrupted service, these shuttle cars must have adequate speed to effect quick trip transfer of loads from the working area to the transportation system. Drive motors "must be built for rugged service" say Goodman engineers in specifying Dow Corning silicone insulation. *No. 645*

DIELECTRIC GEL *(Continued)*

and permits test probes to be accurately directed to connections for instrument checks. Self-healing, the gel automatically seals punctures when probes are withdrawn.

Dielectric Gel is highly resilient. It exerts no stress on delicate parts either during or after cure, and will not damage sensitive parts as a result of fluctuating temperatures — a problem with rigid potting materials. What's more, the gel provides potted parts with excellent protection against shock and vibration. *No. 646*

new literature and technical data on silicones

Design Material Selector—Arranged as a materials selection guide, an 8-page reprint from Electronic Design lists solutions to each of more than a dozen problems confronting designers of electrical equipment. This reprint is a guide to data on specific silicone products that help electronic systems meet a wide range of service conditions and assure longer, more reliable performance demanded of today's equipment. *No. 647*

Specifying Problem—Economical, strong, lightweight, dielectric materials made from silicone molding compounds may be the answer to your specifying problems. Parts and structural components molded from Dow Corning silicone molding compounds give excellent service despite such environmental conditions as moisture, heat, corrosion and fungus. The typical properties and performances offered by silicone molding compounds are compiled in a brochure. *No. 648*

Voids Avoided — Self-adhering Guide Line triangular tape made from Silastic, the Dow Corning silicone rubber, is ideal for insulating form wound coils of motors and generators. Because it bonds into a homogeneous insulation wall, flexible Guide Line tape can eliminate voids without the use of filling materials. Also good for insulating connections and terminals, triangular tape's shape permits easy and economical processing, assures uniform insulation wall thickness. A recent reprint from Insulation magazine gives full details. *No. 649*

Design Versatility — Lightweight, strong, inert, and easy to fabricate, silicone-glass laminates are used in the design and manufacture of a variety of consumer and industrial products. Applications, tables of physical and dielectric properties, illustrations of various parts, and sources of silicone-glass laminate parts are included in a 4-page brochure. *No. 650*

A Lubricant Manual presents some of the more important aspects of the selection of the most suitable oils or greases for instrument ball bearings. Portions are devoted to military specifications applicable to miniature instrument bearing lubricating, and special attention is given to lubricants with special properties. An invaluable reference work for your design files. *No. 651*

Dow Corning Corporation, Dept. 7018, Midland, Michigan

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Dow Corning CORPORATION
MIDLAND, MICHIGAN

ATLANTA BOSTON CHICAGO CLEVELAND DALLAS LOS ANGELES NEW YORK WASHINGTON, D. C.

CANADA: DOW CORNING SILICONES LTD., TORONTO GREAT BRITAIN: MIDLAND SILICONES LTD., LONDON FRANCE: ST. GOBAIN, PARIS

FILE FACTS

Diffusion Coatings

A large number of elements can be diffused into the surface of metals to improve their hardness and resistance to wear, corrosion and oxidation. Diffusion coatings (sometimes called cementation coatings) are applied by heating the base metal in an atmosphere of the coating material, which diffuses into the metal.

Calorized

Aluminum (calorized) coatings are applied by diffusion to carbon and alloy steels to improve their resistance to high temperature oxidation. They can be applied by treating the metal in a powdered aluminum compound or in aluminum chloride vapor, or by spraying the aluminum on and subsequently heat treating it. The alloy coating formed (about 25% aluminum) protects the metal by sealing it from the surrounding air. The coatings range in depth from 5 to 40 mils and permit parts to remain serviceable for many years at temperatures up to 1400 F. They have also been used for intermittent exposure as high as 1700 F. Typical high temperature uses are chemical and metal processing pots, bolts, air heater tubes, and parts for furnaces, steam superheaters and oil and gas polymerizers.

Carburized

Carburizing allows steels to retain high internal strength and toughness and at the same time have high surface hardness. The hardened surface is produced by introducing carbon into a steel surface by heating the metal above the transformation temperature while it is in contact with a carbonaceous material which may be a solid, gas or liquid.

In general, carburizing is limited to steels low enough in carbon (below about 0.45%) to take up that element readily. Plain carbon steels are generally used if surface hardness is the principal requirement and core properties are not too critical. Alloy steels must usually be used if high strength and toughness are needed in the core. Typical applications are gears, cams, pawls, racks and shafts.

Chromized

Chromizing is the process of diffusing chromium into ferrous metals to improve their resistance to corrosion, heat and wear. Typical of the chromizing methods that have been developed is one in which the parts to be treated are packed in a proprietary powdered chromium compound and heated to 1500 to 1900 F. This method produces a high chromium-iron alloy on ferrous metals with a low carbon content. The case (3 mils thick) exhibits good resistance to scaling and corrosion at high temperatures. A chromium carbide case is produced on high carbon materials such as cast iron, iron powder, tool steel and plain carbon steels containing over 0.40% carbon. This case (½ to 2 mils thick) has a hardness of 1600 to 1800 VPN.

Cyanided, Carbonitrided

Both cyaniding and carbonitriding produce a hard and wear resistant surface on low carbon steels. Both methods cause carbon and nitrogen to diffuse into the surface of the base metal. The case developed has high hardness after quenching. The methods differ in that a liquid bath is used in cyaniding, whereas a gas atmosphere is used in carbonitriding.

In general, cyaniding and carbonitriding are used with the same base metals and for the same applications as carburizing. Warpage is usually less serious than in carburizing. Quenching is usually required for full hardness but file hardness can be obtained without quenching.

Nickel-Phosphorus Coated

With some exceptions, nickel-phosphorus coatings can be roughly classified as diffusion coatings. The coatings are prepared from nickel oxide, dibasic ammonium phosphate and water, and are applied to ferrous surfaces just like a paint. Subsequent heat treatment in a controlled atmosphere produces coatings with a degree of corrosion resistance approaching that of stainless steel and the high nickel alloys. The coatings have little porosity and high resistance to heat and abrasion.

Nitrided

Nitriding is a means of improving wear resistance. In the most widely used process, steel is exposed to gaseous ammonia at a temperature (about 1000 F) suitable for the formation of metallic nitrides. The hardest cases are obtained with aluminum-bearing steels such as the Nitralloys. Where lower hardness is acceptable, steels containing no aluminum, such as medium carbon steels containing chromium and molybdenum, can be used.

Stainless steels can also be case hardened by nitriding (e.g., Malcolmizing). Straight chromium steels are more readily nitrided than nickel-chromium steels, although both are used. Tool steels can also be given a thin hard case.

Nitriding produces minimum distortion. Some growth occurs, but this can be allowed for. In general, nitriding is used for the same applications as carburizing.

Sherardized

Sherardizing is the process of applying zinc coatings to ferrous and nonferrous metals to improve their corrosion resistance. The coatings are applied by heating parts in a zinc powder at 650 to 700 F for 3 to 12 hr.

Sherardized zinc coatings are not as protective as plated or hot dip zinc coatings; however, they can be applied in more uniform thicknesses. Ordinarily, they are quite satisfactory for mild atmospheres. Principal applications are small steel parts such as nuts, bolts and washers, or castings that must resist atmospheric corrosion.

Siliconized

Substantial improvements in the wear resistance and hardness of steel and iron parts can be obtained by impregnating with silicon (about 14%). The most wear resistant cases are formed on low carbon, low sulfur steels. High carbon, low sulfur steels can also be impregnated, although treatment time is longer. White and malleable iron can also be siliconized; siliconizing of gray irons is not recommended.

The case of a siliconized surface (about 5 to 10 mils) is rather brittle, hardness varying from Rockwell B80 to B85. Siliconized sufaces are virtually nongalling and are especially effective in resisting combined wear and corrosion.

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Edited by
John A. Mock

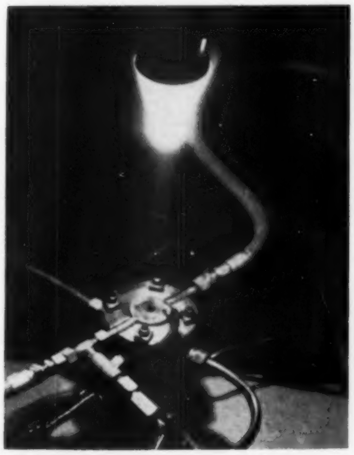
Thanks to small palladium additions . . .

Titanium Alloys Resist Reducing Acids

■ One of the major reasons for titanium's popularity in the process industries is its excellent resistance to highly oxidizing environments such as boiling nitric acid. One of its major drawbacks has been its lack of resistance to reducing environments such as hydrochloric acid. Thanks to a new discovery, however, titanium alloys are now being made which are resistant to both oxidizing and reducing acids.

According to Union Carbide Metals Co., Div. of Union Carbide Corp., the addition of as little as 0.1% palladium increases titanium's resistance to corrosion from reducing acids from more than 1 ipy to less than 0.01 ipy. This improvement can also be achieved with small additions of most of the other noble metals—platinum, rhenium, ruthenium, iridium, osmium, rhodium and gold. The noble metal additions have no effect on the mechanical properties or fabricability of titanium.

According to Dr. Milton Stern of the Metals Research Laboratories, here's how the noble metal addition makes titanium more resistant to reducing acids: A noble metal is essentially insoluble in the corrosive environment and has a high exchange current for the hydrogen ion reduction process. When added to titanium, the noble metal appears at the surface of the alloy, creates a bi-electrode (galvanic couple), and serves as a site with a low hydrogen overvoltage. This results in passivity and a marked decrease in the rate of corrosion. Only one atom of palladium is needed for every 2,000 atoms in the alloy.



Rocket nozzle *made of Glasrock fused silica glows with heat after being fired from special launching pad in simulated test.*

Fused Silica Shapes Have Good Thermal Shock Resistance

■ Crack-free, self-supporting fused silica shapes in sizes up to 6 ft square by 11 in. thick are produced by new forming and bonding techniques, details of which have not been revealed. One of the outstanding properties of the silica shapes is their good thermal shock resistance—they can be heated to 2000 F and rapidly cooled to room temperature without cracking.

The producer, Glasrock Corp., 1101 Glidden St. NW, Atlanta, Ga., says, "Much larger pieces are contemplated in the near future, and there seems to be no practical limit to sizes that can be produced by the new forming and bonding techniques." Starting material for the fused silica shapes is 99.9% pure silica sand. The sand is melted into silica glass, then crushed, ground and fabricated into the silica shapes called Glasrock.

Potential uses

According to the producer, the fused silica shapes have potential use in the following applications:

1. Permanent molds for iron, steel and other metals.

2. One-piece furnace hearths and car tops that can be exposed

Fused silica shapes *made by a new fabricating technique.*

to temperatures up to 2000 F.

3. One-piece, self-supporting sides, roofs and removable ends for furnaces and kilns operating at temperatures up to 3000 F.

4. Nose cones for missiles and rockets.

5. Fixtures and containers for use in furnaces operating at temperatures below 2000 F.

6. Burner rings, ladles and crucibles for induction melting.

7. Piping for molten metals.

Nuclear and chemical applications for fused silica shapes are presently being investigated. (For information on other uses of fused silica, see M/DE, Feb '57, p 106.)

Properties

Thermal shock resistance—Fused silica shapes remain whole through numerous immersions in molten iron with alternate cooling to near room temperature. It appears that if one cycle will not start cracking, neither will repeated cycles at the same time and temperature. If a fused silica shape does crack, it is necessary to heat the shape to a temperature of about 500 F to close up most of the cracks.

Thermal conductivity — Glasrock shapes made of coarse material have a thermal conductivity of more than 6 Btu/hr/sq ft/°F/ft at 1000 F, whereas shapes made of finer grain material have a thermal conductivity of less than 3 at 200 F.

Chemical resistance—Preliminary tests show fused silica shapes have good resistance to most acids, and fair resistance to alkalis.

PROPERTIES OF GLASROCK

PHYSICAL PROPERTIES	
Density, lb/cu in.	
Slip Castings	0.072
Aggregate Castings	0.065
Porous Castings	0.361
Color	White
Luster	Matte
Crystal Structure	None
Porosity, %	
Slip Castings	12-18
Aggregate Castings	8-15
Porous Castings	50-60
Firing Shrinkage, %	
Slip Castings	1-1.5
Aggregate Castings	0.1-0.5
Firing Temperature, F	1200-2100
Melting Point, F	3100
MECHANICAL PROPERTIES	
Ten Str (slip castings), psi	1,500
Compressive Strength, psi	
Slip Castings	20,000
Aggregate Castings	15,000
Modulus of Rupture, psi	
Slip Castings	4,200
Aggregate Castings	2,000
Mohs Hardness	7
Max Operating Temp, F	
Continuous	2000
Cyclic	3000
ELECTRICAL PROPERTIES	
Dielectric Constant (1 mc)[a]	
Room Temperature	3.17
1500 F	3.18
2000 F	3.28
2500 F	3.42
Loss Factor (1 mc)[a]	
Room Temperature	0.0002
1500 F	0.0006
2000 F	0.007
2500 F	0.012

[a]Tests performed on slip castings by Melpar, Inc.

First Successful Large Beryllium Forging

■ Shown in the photo at left is what is said to be the first large beryllium part ever forged. This development is important because it eliminates the two major obstacles to beryllium's use as a structural engineering material—brittle behavior and lack of producibility.

According to Wyman-Gordon Co., the closed-die forging technique 1) increases beryllium's ductility and isotropy to the level of that of the strong aluminum alloys; and 2) produces large shapes that require a minimum of machining (previously, parts had to be machined from rough blocks).

The use of beryllium in structural applications is important because it offers an excellent combination of properties: light weight (about the same density as magnesium), good modulus of elasticity (about 1½ times that of steel), excellent strength-weight ratio, good corrosion resistance, low thermal-neutron-absorption cross section, and resistance to high and low temperatures.

Aluminum Alloy Resists 600 F

■ A new aluminum alloy which is said to offer good strength at temperatures up to 600 F has been developed by Aluminum Co. of America. The new alloy is designated X2219-T6 and is available in experimental quantities in the form of sheet, plate, extrusions and forgings. The alloy is expected to prove useful in special applications in high speed aircraft, missiles and space vehicles.

Composition and properties

Alloy X2219-T6 contains 6.0 copper, 0.30 manganese, 0.10 vanadium and 0.15% zirconium. In the solution heat treated and aged condition, extrusions of the new alloy offer good tensile, stress-rupture and fatigue properties at elevated temperatures. After 100 hr at 600 F, for example, tensile properties of X2219-T6 are about twice as good as those of alloy 2024-T6, the aluminum alloy currently being used for elevated temperature service. In addition, the alloy is said to be highly resistant to stress corrosion cracking. Room and elevated temperature tensile properties are given in the accompanying table.

TENSILE PROPERTIES OF X2219-T6 EXTRUSIONS[a]

	Tensile Strength, 1000 psi		Yield Strength (0.2% offset), 1000 psi		Elongation, %	
Temperature ↓	Long.	Trans	Long.	Trans	Long.	Trans
THICK SECTION						
Rm Temp	62.0	61.2	43.6	40.3	15.0	8.0
300 F	53.3	51.3	38.7	37.4	15.0	8.0
400 F	41.9	40.2	33.6	32.6	18.0	20.0
500 F	28.3	28.8	22.2	21.2	21.0	21.0
THIN SECTION						
Rm Temp	63.1	—	44.6	—	8.8	—
400 F	37.7	—	31.0	—	16.0	—
500 F	27.8	—	24.4	—	16.0	—

[a]Elevated temperature values were measured after 100-hr exposure at temperature.

Welded Honeycomb Is Strong, Lightweight

by **J. R. Campbell,** *Consultant*
John J. Foster Mfg. Co.

***Fig 1**—Stresskin honeycomb structure.*

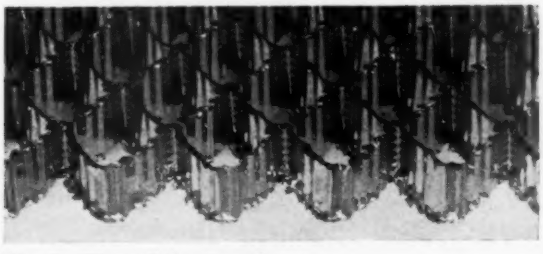


***Fig 2**—Flanged honeycomb core.*

■ A resistance welded honeycomb structure called Stresskin (see Fig 1) may replace brazed and adhesive bonded honeycomb structures in a number of industrial and commercial applications.

Advantages of the welded construction are: 1) it is light in weight; 2) it contains no contaminating materials; 3) it has high strength and good heat resistance; 4) it is made to close dimensional tolerances; and 5) it requires no machining or trimming as is often the case with brazed honeycomb structures.

Honeycomb core

The basic element of the construction is a flanged honeycomb core called Stress/Core (see Fig 2). The thin upper and lower edges of the core cells are formed into a reinforcing flange at right angles

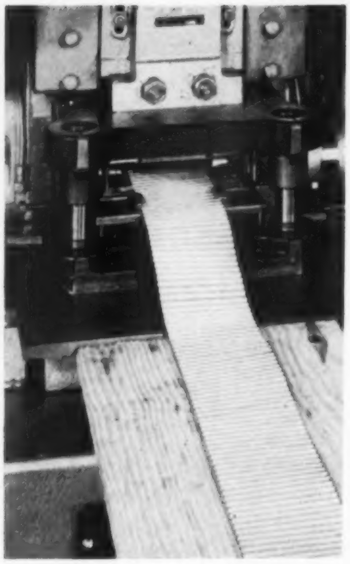


***Fig 3**—Automatic press turns out flanged and corrugated metal strip used in Stresskin honeycomb structures.*

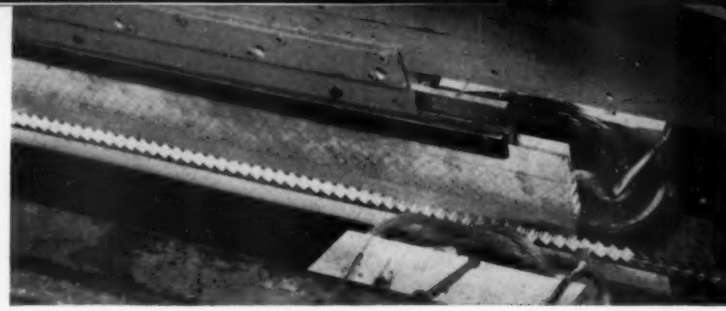


***Fig 4**—Special flange welding head joins flanged strips one at a time to face sheets. This welding head then retracts and a node welding head moves in to weld the nodes together.*

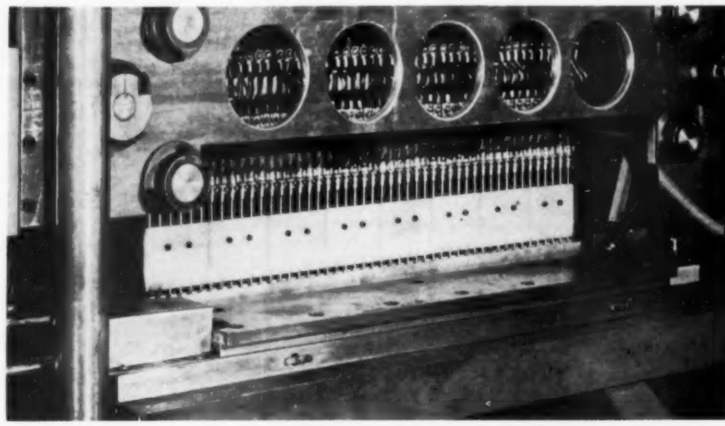


***Fig 5**—Resistance welding machine in which Stresskin honeycomb structures are fabricated into a finished product in one operation.*

to the core cell walls. The core cells are made of corrugated metal strip similar to that shown in Fig 3. The flange, approximately 0.04 in. wide, provides sufficient contact area so that the metal core can be welded directly to facing materials. The flange adds no appreciable weight to the core as compared to the weight of flux and brazing alloys used in brazed honeycomb structures.

To date cores have been made from types 301, 302, 321 and 17-7 PH stainless steels. Experimental cores have been made from tantalum, titanium, and 2618 and 2020 aluminum alloys.

How structure is made

The honeycomb structure is fabricated in one operation by a resistance welding technique in which two welding heads are used, one for flange welding and the other for node welding. In fabricating, flanged strips are first welded one at a time to face

(continued on p 120)

Mr. Campbell, the author, was given an Award of Merit in M/DE's 1958-59 Awards Competition for Best Use of Materials in Product Design for the welded honeycomb discussed in this article. (For more information on the Awards Competition, see M/DE, May '59, p 121.)

MORE WHAT'S NEW IN MATERIALS

For more information, circle No. 382 ➤

sheets (see Fig 4). The flange welding head is then retracted and the node welding head moves in to weld the nodes to each other after each strip has been welded to face sheets. Flange welds are spaced approximately 0.030 in. apart and node welds 0.050 in. The entire welding process is continuous and takes place on a machine similar to the one shown in Fig 5. At present, it takes about 45 sec to weld a 4-ft core strip to face sheets and to each other.

Involved inspection procedures commonly used in the manufacture of brazed or adhesive bonded structures are not required in the manufacture of Stresskin structures. A specially developed electronic weld pulse control is used to detect and correct imperfections at any stage of manufacture. As a result, inspection costs are drastically reduced.

Properties and uses

Tests on Stresskin honeycomb structures are not yet complete. However, peel tests show that the resistance welded bond between facing and core is sufficient to tear the core.

The small amount of heat involved in manufacturing does not affect the tensile strength and other properties of metals used in Stresskin honeycomb structures. Thus, the retention of tensile strength should make Stresskin structures particularly useful at high temperatures.

Probably one of the biggest uses of Stresskin honeycomb structures will be in aircraft structural parts such as wing structures, fuselage sections, fins, vanes and instrument cabinets. Some airframe manufacturers are now being supplied with the honeycomb structures on a limited basis. The resistance welded honeycomb is also expected to find use as a structural material in missiles.

One-Part Epoxy Resin for Electrical Parts

A one-part epoxy molding powder has been developed that has good electrical properties at high temperatures, good dimensional stability, low mold shrinkage, and long storage life. The material is called

***Typical parts** that can be made of a new one-part epoxy compound.*

Hysol 8610 and is available from Houghton Laboratories, Inc., Olean, N. Y.

The molding powder has a heat distortion point exceeding 300 F and cures at moderate temperatures. Potential uses for the material include coil and resistor bobbins, relay assemblies, connector plugs, switchgear, and shells for electrical parts. Other potential uses: dental equipment that is subjected to steam cleaning and filters that must resist severe chemical attack.

Aluminum Alloy for Structural Applications

Additional information on the properties and uses of a relatively new aluminum extrusion alloy has been released by Aluminium Ltd. Sales, Inc., 630 5th Ave., New York 20. The alloy, called Alcan B51S, was introduced last year (see M/DE, Oct '58, p 4). It is available in the form of ingots.

According to the producer, the structural alloy has medium strength and good resistance to stress corrosion cracking. It also has good resistance to rural, marine and industrial atmospheres. The alloy is not recommended for use in salt water or brine solutions. It has a composition of 0.80 magnesium, 0.80 manganese, 1.30 silicon, 0.10 copper,

PROPERTIES OF ALCAN B51S

Condition ➡	T4	T6
Tensile Strength, 1000 psi	36	46
Elongation (2 in.), %	20	13
Yield Strength, 1000 psi	22	43

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0.60 iron, 0.20 titanium and 96.20% aluminum.

The aluminum alloy is expected to be used for appliance trim, pipes, portable bridges, window frames, boat masts, tubular furniture, railings, decking, aircraft hanger doors, ladders and ski poles.

Epoxy Resins Useful for Adhesives, Tools

Two liquid epoxy resins—a heat resistant grade and a flexible grade—have been developed for use as adhesives, laminating and casting resins, and tools.

1. Heat resistant grade

Marblette Corp., 37-31 30th St., Long Island City 1, N. Y. has introduced a liquid epoxy resin available in two formulations. Resin 617-A is aluminum-filled, whereas 617-C is clear. Both resins are said to withstand temperatures up to 500 F. The materials are expected to be used as laminating and casting resins and as adhesives. Marblette's resin has a tensile strength of 10,700 psi at room temperature and 4500 at 300 F. It has a flexural strength of 41,000 psi at 400 F and 22,000 at 500 F. When used as an adhesive to bond aluminum to aluminum, the resin has a shear strength of 1380 psi at 400 F.

2. Flexible grade

Epon X-81 is the name given to a flexible epoxy resin developed by Shell Chemical Corp., 50 W. 50th St., New York 20. A cured sample of the resin had an elongation of 100% before it broke, compared to 7% for a conventional epoxy. The resin is also said to be resistant to temperature changes. Potential uses for the new material, which sells for 95¢ per lb, include adhesives, dies and fixtures, coatings and encapsulants.

Cupro-Nickel Alloys Sold as Sheet, Strip

Sheet and strip made from three cupro-nickel alloys (70-30, 80-20 and 90-10) are now available from Bridgeport Brass Co., 30 Grand St., Bridgeport 2, Conn. Previously, the

alloys were available only in the form of tubing.

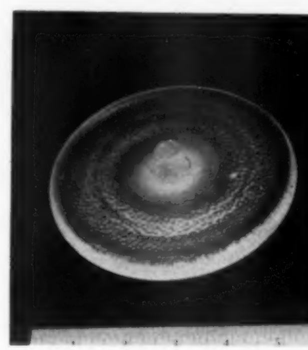
The alloys are said to have good heat and corrosion resistance. They can be hot or cold worked, and can be joined by soldering, brazing or welding.

Sheet, strip and tubing made from the three alloys are particularly suited for condensers, salt water evaporators, high temperature processing equipment, heat exchangers, evaporators, automobile transmission coolers, radiator sections, small tanks, strainers and filters.

Adhesive, Sheeting for Vinyl-Metal Laminates

1. Adhesive

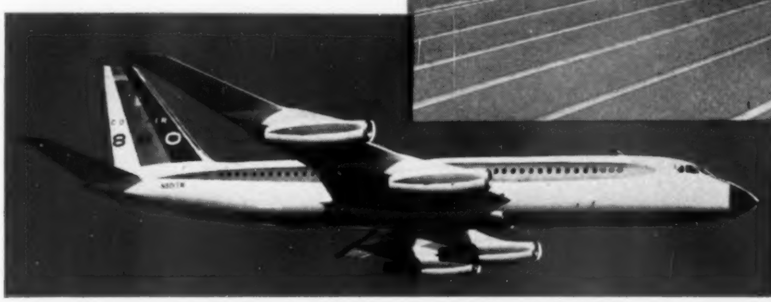
A vinyl-metal adhesive has been developed that withstands: 1) boiling water for 30 min; 2) dry heat for 7 days at 200 F; 3) tap water for 240 hr at 70 F; 4) 100% RH for



Large synthetic sapphire—Pictured above is a synthetic sapphire window that can be produced in diameters up to 5 in. and in large contoured shapes. The window, valued at $1000, is used in infrared, ultraviolet and microwave applications. The sapphire part was made by special growing techniques developed by the Crystal Products Dept. of Linde Co., Div. of Union Carbide Corp., 30 E. 42nd St., New York 17. (For more information on synthetic sapphires, see M/DE, Sept '57, p 161.)

New ideas in **NYLON**

Inside the new Convair 880, strips of Spencer Nylon are used in the cargo area to attach floor panels to structure of aircraft, as well as to serve as a slide strip for cargo. (See story below.)



How Spencer Nylon helps cut weight in world's fastest jet transport:

When you specify materials to be used in building an airplane that will carry 8,630 pounds of cargo at a top cruising speed of 615 mph, every ounce counts. You must keep weight low to get maximum payload, yet you cannot sacrifice strength and durability.

That's why Spencer Nylon 606 is being used for the cargo slide strips in the new Convair 880—the world's fastest jet transport.

Even lighter than aluminum, the Spencer Nylon cargo slide strips are also smoother than aluminum! About 580 feet of Spencer Nylon cargo slide strips are used in every Convair 880.

Extruded by W. S. Shamban & Co. of Culver City, California, and Fort Wayne, Indiana, the nylon slide strips have the extreme abrasion resistance and low friction properties needed to withstand the punishment of loading and unloading cargo.

Why Spencer Nylon? Shamban reports that they chose Spencer Nylon for two reasons: (1) Spencer Nylon extrudes better and (2) holds the shape while maintaining close tolerances.

Add to this the light weight and high impact resistance of Spencer Nylon, and you can see why so many designers and manufacturers are turning to Spencer Nylon for the answer to a wide variety of problems.

If you would like to know more about the special properties of Spencer Nylon, write to Spencer Chemical Company, Dwight Building, Kansas City 5, Missouri.

SPENCER®

SPENCER NYLON

SPENCER CHEMICAL COMPANY

GENERAL OFFICES, DWIGHT BUILDING, KANSAS CITY 5, MISSOURI

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1000 hr at 160 F; and 5) detergent and salt solutions for 200 hr at 140 F.

The new adhesive, called No. A-978-B Cement, was developed by B. F. Goodrich Industrial Products Co., Div. of B. F. Goodrich Co., Akron, Ohio. The producer says that sheet steel bonded to vinyl with the adhesive can be stretched 35% without weakening the bond or damaging the vinyl coating.

The thermosetting adhesive, applied by brush, spray or roller, develops a semi-rigid, tough bond after baking 10 min at 400 F.

2. Sheeting

Production of a new, semi-rigid vinyl sheeting for vinyl-to-metal applications was announced recently by General Tire & Rubber Co., Jeannette, Pa. The plastic, known as Boltaflex 500, is said to resist wear, stains, cracking, chipping, peeling, delamination, weather, salt water and fire.

The vinyl sheeting stands up well under machining and fabricating processes currently used in metalworking, and can be bonded to metal by conventional methods.

Boltaflex 500 is available in 0.010, 0.012 and 0.014-in. thicknesses. It comes in 36, 48 and 72-in. widths which can be printed in as many as six colors. Overall embossing is possible up to 72-in. widths.

Asbestos, TFE Resin Resist Liquid Oxygen

Fluorocarbon greases and oils, TFE resin, asbestos and polyethylene resins can be used safely with liquid oxygen. Other organic materials, such as synthetic rubbers, silicone oils and greases, epoxy resins, petroleum-base oils, nylon resins and cellulose-base papers cannot be used safely with liquid oxygen. These are the conclusions derived from a series of "impact sensitivity" tests conducted by D. E. Clippinger and G. J. Morris of Martin Co.

Research was prompted by rocket engine and rocket plane manufacturers who noted that when some organic materials came in intimate contact with liquid oxygen, they became prone to detonation when sub-

What's new IN MATERIALS

jected to certain impact energies. Specifically, when liquid oxygen was accidently spilled on asphalt and inadvertently stepped on, the asphalt often exploded. Also, leather gaskets immersed in liquid oxygen and subjected to surge impact detonated with disastrous effects.

The tests conducted by Clippinger and Morris showed that 63% of the materials tested were impact sensitive. Of these, about 75% were moderately to extremely sensitive. The two researchers found that impact sensitivity is often related to the thickness of the specimen, i.e., thin specimens detonate, whereas thick specimens of the same material do not detonate.

How tests were performed

Impact sensitivity tests were conducted by delivering a calculated impact energy to a specimen immersed in liquid oxygen. One detonation in 60 or none in 20 impacts made a material acceptable as "impact insensitive."

Equipment used in the tests consisted of a guillotine impact tester equipped with a 71.75-lb weight which was set to fall a distance of 1 ft. A hammer mounted on the weight transmitted the impact force to a striker resting on the specimen being tested. The weight was dropped by a quick-release mechanism actuated by a solenoid. Materials to be tested were cut into ½-in. squares 0.050 in. thick.

A closed circuit television system permitted test personnel to view impact from inside a blockhouse. Motion pictures were taken of the impact at speeds up to 1/128 sec.

Quick Spot Test for Polyurethane Foams

A spot test for differentiating polyether from polyester-based urethane foams, elastomers and coatings has been developed by Mobay Chemical Co., 1815 Washington Rd., Pittsburgh 34. The entire test is said to take about 1 min.

The test works as follows:

1. A few drops of potassium hydroxide solution are placed on a urethane foam surface.

2. A few drops of hydroxylamine hydrochloride solution are then placed

For more information, turn to Reader Service card, circle No. 448

on the same spot.

3. The spot is then acidified with hydrochloric acid.

4. A few drops of ferric chloride solution are added and the color noted.

In the presence of polyesters the spot will turn violet immediately.

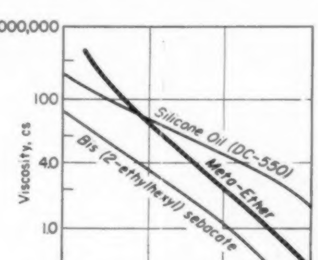
Meta-Ether Lubricants Useful up to 1000 F

Lubricants for use in the temperature range 700 to 1000 F have come out of the development of a class of materials called polyphenyl ethers. Of 19 polyphenyl ethers evaluated, meta-polyphenyl ether has the best liquid properties, the lowest pour point and the best viscosity-temperature relationship. The material is now available in developmental quantities from Monsanto Chemical Co., St. Louis, Mo.

Meta-polyphenyl ether has a calculated "useful life" of 80 hr at 900 F, compared to 0.1 to 3 min for presently used lubricants. The decomposition point of the material falls between 820 and 860 F. This means that the ether is as stable at 840 F as silicones are at 740 F, hydrocarbons at 660 F, and esters at 540 F.

Properties and uses

Although developmental work is directed primarily at future turbojet lubricant requirements, meta-polyphenyl ether is also expected to find use as a high temperature hydraulic fluid, a base stock for high temperature and radiation resistant greases, a heat transfer medium,



Viscosity-temperature slope *of meta-ether and two other lubricants.*

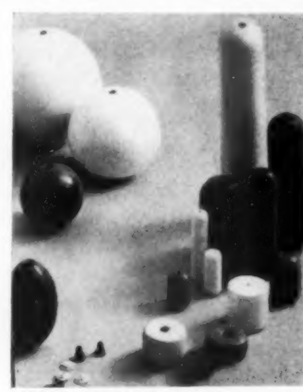
and a nuclear reactor coolant.

Engineering data on meta and other polyphenyl ethers were given by W. C. Hammann and E. S. Blake of Monsanto Chemical Co. at the 135th National Meeting of the American Chemical Society held recently in Boston. A summary follows:

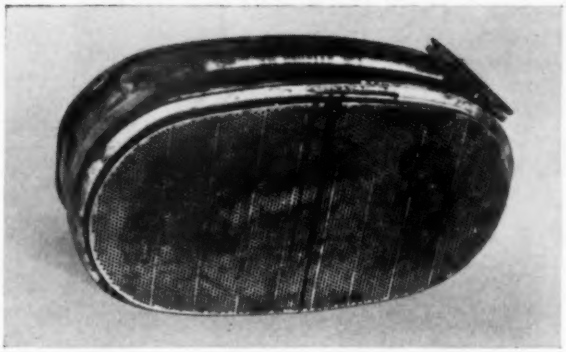
Thermal stability—The high decomposition points (temperature at which a compound decomposes) of the polyphenyl ethers shows that they are more resistant to thermal degradation than any other class of compounds tested, with the exception of polyaromatic hydrocarbons.

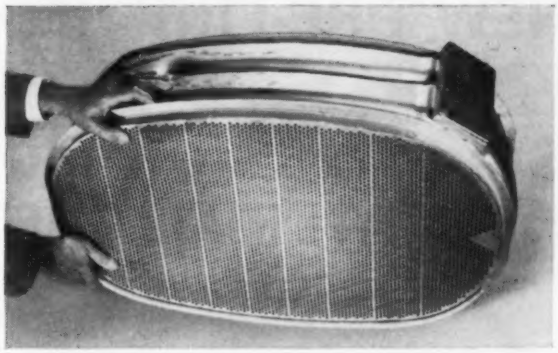
Hydrolytic stability—The polyphenyl ethers are unaffected by water at 570 F and by concentrated hydriodic acid at 480 F. However, they do hydrolyze slowly in dilute alkalis at 570 F. In contrast, esters, silicones and silicates hydrolyze rapidly in dilute acids and alkalis at temperatures below 210 F.

Oxidative stability—The polyphenyl ethers have good resistance to



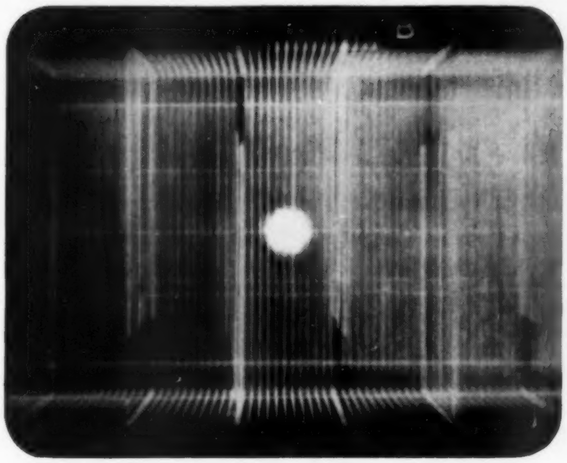
Vinyl plastisol shapes—The molded, one-piece vinyl plastisol shapes shown here are said to be leakproof and extremely buoyant. The parts are expected to find use in the chemical and paper industries because of their good chemical resistance. They are also expected to be useful as floats for valves. The hollow plastics shapes are supplied in durometer hardnesses ranging from A50 to A100. They are available from Polyco, Inc., 146 Roswell St., Smyrna, Ga.

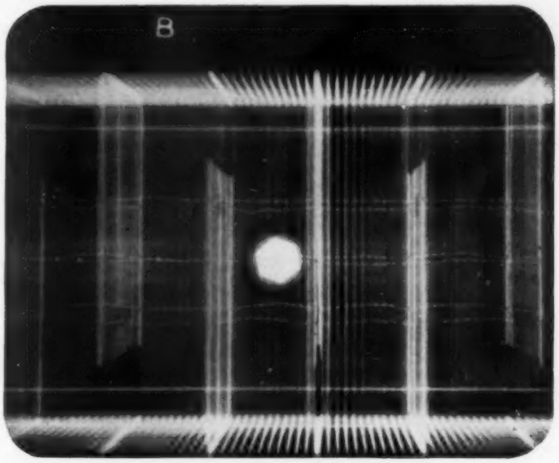




An oil cooler as it comes from the airplane engine. Radiograph below shows accumulations of sludge and dirt on the tubes.

After cleaning, the oil cooler is ready to return to its job. Radiograph below shows dirt gone and passages unrestricted.





To keep an engine's bloodstream clean

OIL COOLERS are vital to today's aircraft engines. At overhaul time they must go back on the engine clean as new. No minute particles of carbon or metal can remain to be a threat to the renewed engine. Cleaning them has become a specialty with SMS Instrument and Accessories Corp. of Idlewild Airport, N. Y. C.

To show that each cooler they clean is free of debris, it is sent to Industrial X-ray Incorporated, New Hyde Park, New York, to be radiographed. And when the cooler goes back to its job, its x-ray certificate of cleanliness goes with it.

In such inspections of assemblies, in quality control, in nondestructive testing, radiography provides a means of "seeing" internal conditions and also a lasting record of what is seen.

Producers of castings, and makers of welded products, find radiography a means of expanding their business and making sure only high-quality work is delivered.

Would you like to learn how it could help you? Contact your Kodak x-ray dealer or the Kodak Technical Representative to talk it over.

X-ray Division . . . **EASTMAN KODAK COMPANY** . . . **Rochester 4, N. Y.**

Read what Kodak Industrial X-ray Film, Type AA, does for you:

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- Gives high subject contrast, increased detail and easy readability at all energy ranges.
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What's new IN MATERIALS

oxidizing agents such as chromium trioxide. Presently available commercial lubricants are severely attacked by oxidizing agents even in the presence of an oxidation inhibitor.

Radiation stability—The ethers, because of their high thermal stability and aromatic structure, have radiation resistance comparable to that of the polyaromatics now used as coolants for nuclear reactors. The average change of the 400 F viscosity of several polyphenyl ethers was 12% at a radiation dosage of 5.5 x 10^{10} ergs per gm.

Liquid properties—Meta-polyphenyl ethers have a liquid range of 35 to 1000 F. Other polyphenyl ethers are solids.

Viscosity—The viscosity level of the ethers as a class is higher than that of presently used lubricants of similar molecular weights. Although this characteristic results in higher pour points for the ethers, it does give them higher and more useful viscosities at temperatures above 400 F.

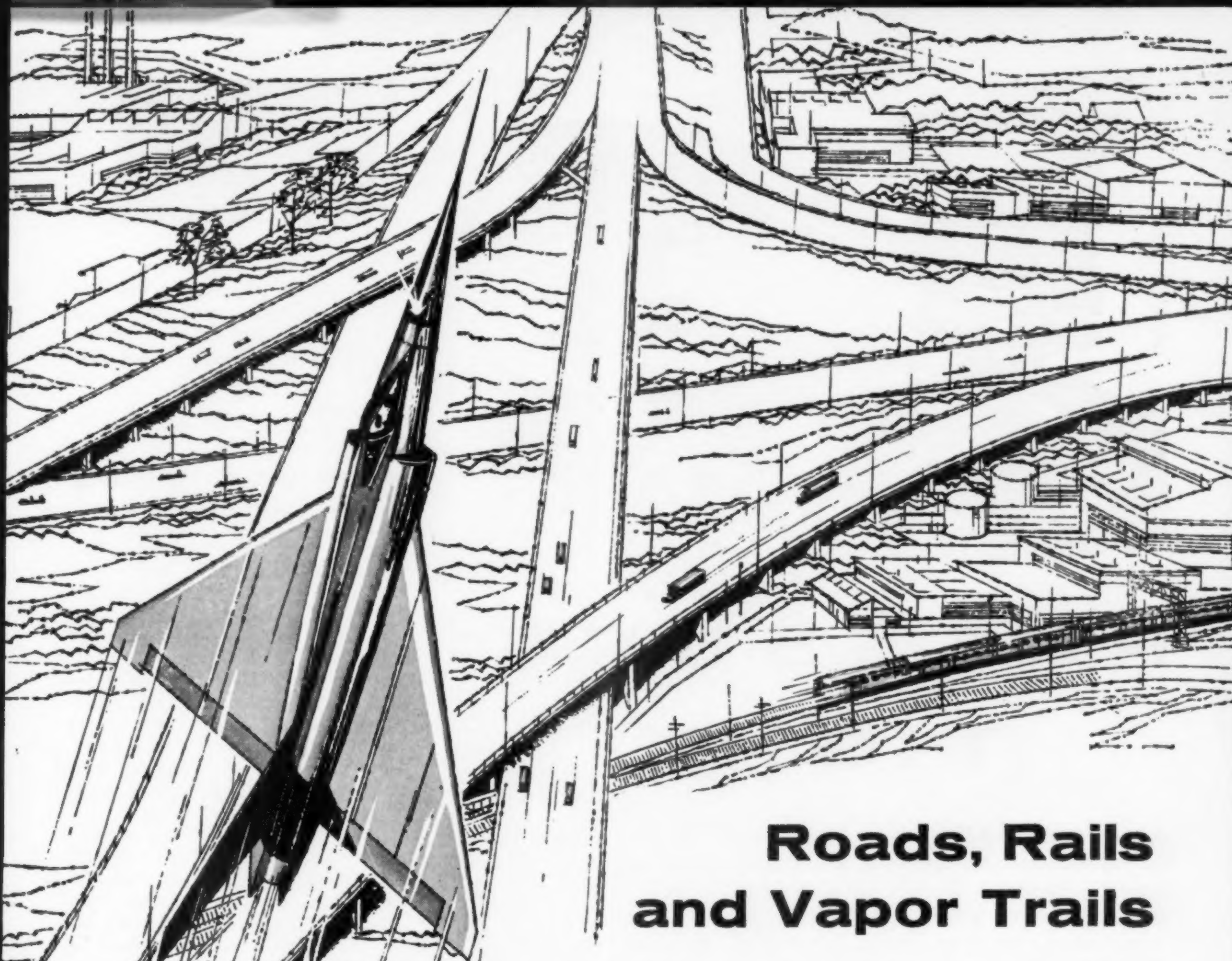
Viscosity-temperature slope—The ASTM viscosity-temperature slope of the meta ether at temperatures above 210 F compares favorably with those of esters, hydrocarbons and silicates in the same molecular weight range. However, the viscosity-temperature slope of the material below 210 F is poor compared with those of other lubricants. The ASTM viscosity-temperature slope is a measure of the rate of change of viscosity with temperature.

Lubricity—Data from the Shell

PROPERTIES OF META-POLYPHENYL ETHER

Decomposition Point, F	862
Useful Life at 900 F, hr	80
Pour Point, F	35
Density (68 F), lb/cu ft	1.19
Molecular Weight	446.5
Viscosity, cs	
50 F	36,700
77 F	1,654
100 F	337.5
210 F	12.72
400 F	2.052
700 F	0.623
ASTM (Viscosity-Temp) Slope	
100-210 F	0.89
210-400 F	0.77
77-400 F	0.85
400-700 F	0.87
77-700 F	0.85

For more information, circle No. 479



Roads, Rails and Vapor Trails

Whether it hugs the earth or rides the stratosphere's jet streams, **modern** transportation has one **un**common denominator—stainless steel.

America's first **supersonic** bomber — the world's **lightest** full-size, railroad passenger car—the trucking industry's **highest capacity** lightweight trailer—all owe their existence to stainless steel's extraordinary strength-weight ratio and almost indestructible good looks.

Every American auto on the road today uses stainless steel functionally and decoratively to protect painted and treated surfaces, because only stainless steel requires no protective treatment to preserve factory freshness and assure lasting customer satisfaction. **And** its unusual workability means that finished product costs are usually lower than for any other bright metal.

Whether your primary interest is function or form, J&L provides **consistent** quality for uniform production.

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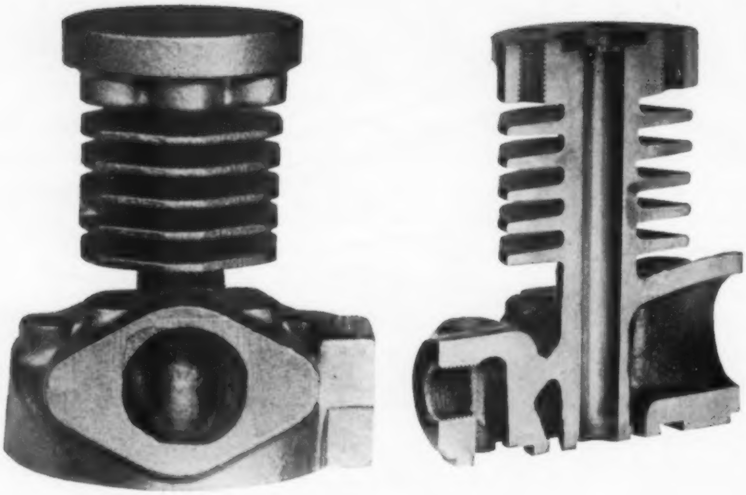


4-ball wear test indicate that the polyphenyl ethers have lubricating properties similar to those of hydrocarbons, esters, silicones and silicates.

Hardening, Brightening Steel Simultaneously

A method for producing crack-free, brightened and hardened steel parts in one operation was described in the Oct '58 issue of the Russian journal *Metalovedenie I Obrabotka Metalov (Metal Science and Treatment)*. The article, translated by Larissa Domikov, Northrop Aircraft, Inc., indicates that steel parts hardened and brightened by the new process are much brighter than hardened parts polished in a separate operation.

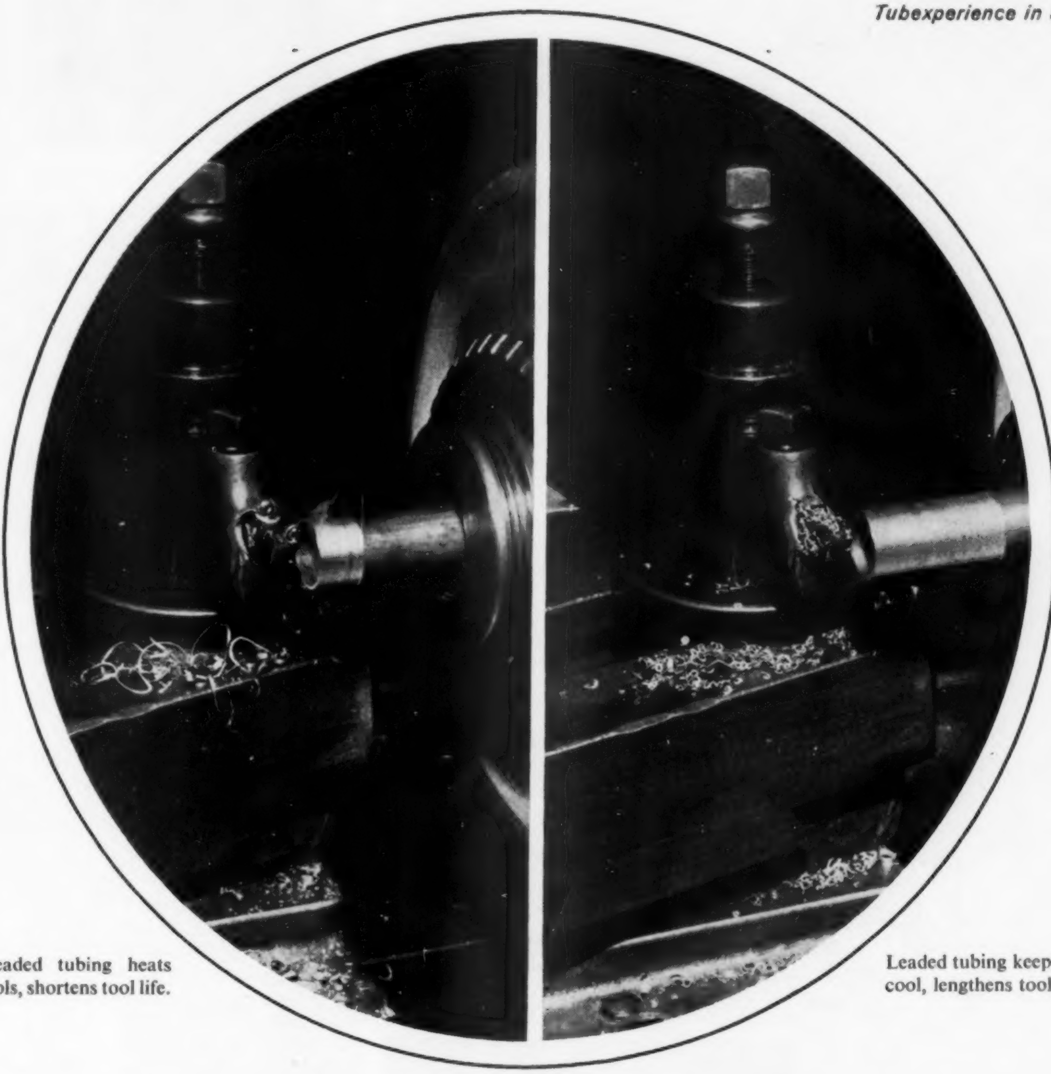
Essentially, the method consists of heating steel parts in a neutral atmosphere or in salt, then quenching in a phosphoric-chromic acid solution. Two lead cathodes are attached to copper bus bars and placed in the solution; a third copper bus bar acts as an anode. Steel parts heated in the neutral atmosphere are connected to the anode by means of Nichrome wires. When quenched in the solution, the red hot steel undergoes simultaneous hardening and electropolishing.

In the hardening and brightening process, the part is anodic, and it discharges active oxygen ions which combine with hydrogen to form water.

Transparent Silicone for Potting Applications

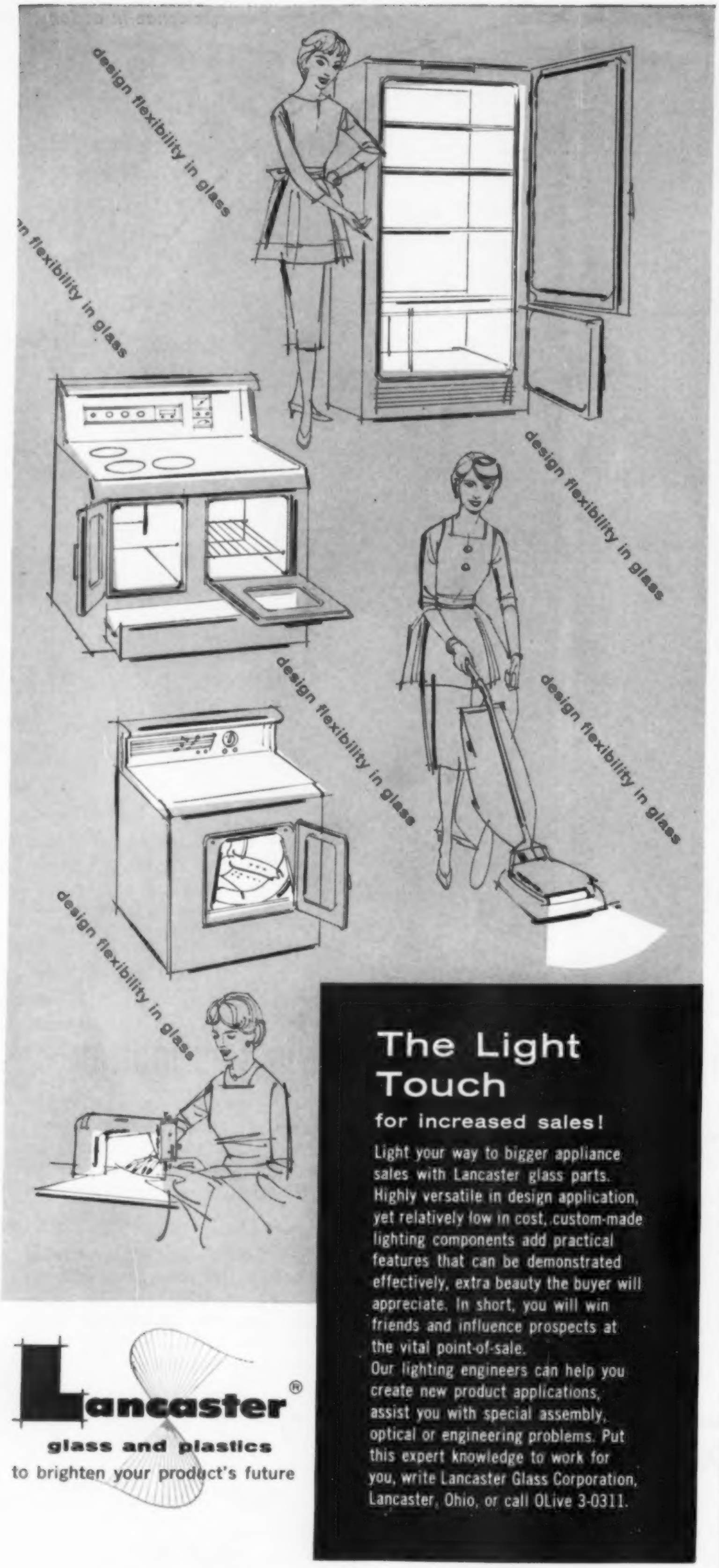
Development of a transparent silicone potting compound that permits visual and instrument checking of individual parts within a potted assembly has been announced by Dow Corning Corp., Midland, Mich. Easily applied as a water-white liquid with the viscosity of molasses, the material readily surrounds components and cures in place to form a resilient mass.

In addition to filling and potting applications, the material shows



Nonleaded tubing heats up tools, shortens tool life.

Leaded tubing keeps tools cool, lengthens tool life.



***Potting compound** is resilient and jelly-like after pouring and curing.*

promise as an impregnant for capacitors, magnetic amplifiers and similar devices.

Circuits of units filled or potted with the transparent material can be located visually and checked by inserting test probes into the silicone gel. The gel completely reseals itself after the test probes have been removed. According to the producer, delicate parts and connections potted with the material are not damaged by fluctuating temperatures, as is often the case with rigid potting materials.

The silicone compound, called XF 1-0042 Dielectric Gel, combines

PROPERTIES OF DIELECTRIC GEL

PHYSICAL PROPERTIES[a]	
Specific Gravity (77 F)	0.970
Viscosity (77 F), cs	700
Flash Point, F	300
Freezing Point, F	—58
Refractive Index (77 F)	1.40
Ther Cond, Btu/hr/sq ft/°F/ft[b]	
300 F	0.169
400 F	0.189
ELECTRICAL PROPERTIES[b]	
Dielectric Strength, v/mil	1000
Dielectric Constant (100 cps)	
75 F	3.00
300 F	2.55
Dissipation Factor (100 cps)	
75 F	0.0001
300 F	0.002
Volume Resistivity, ohm-cm	
75 F	5×10^{14}
300 F	1×10^{14}

[a]Before cure. [b]After cure.

For more Information, turn to Reader Service card, circle No. 447

For more information, turn to Reader Service card, circle No. 381

***Test probes** can be inserted into silicone gel for checking individual parts within the potted assembly.*

excellent moisture resistance with good thermal stability. It has electrical properties comparable to those of electrical-grade silicone fluids.

Hydrogen Does Not Embrittle Aluminum

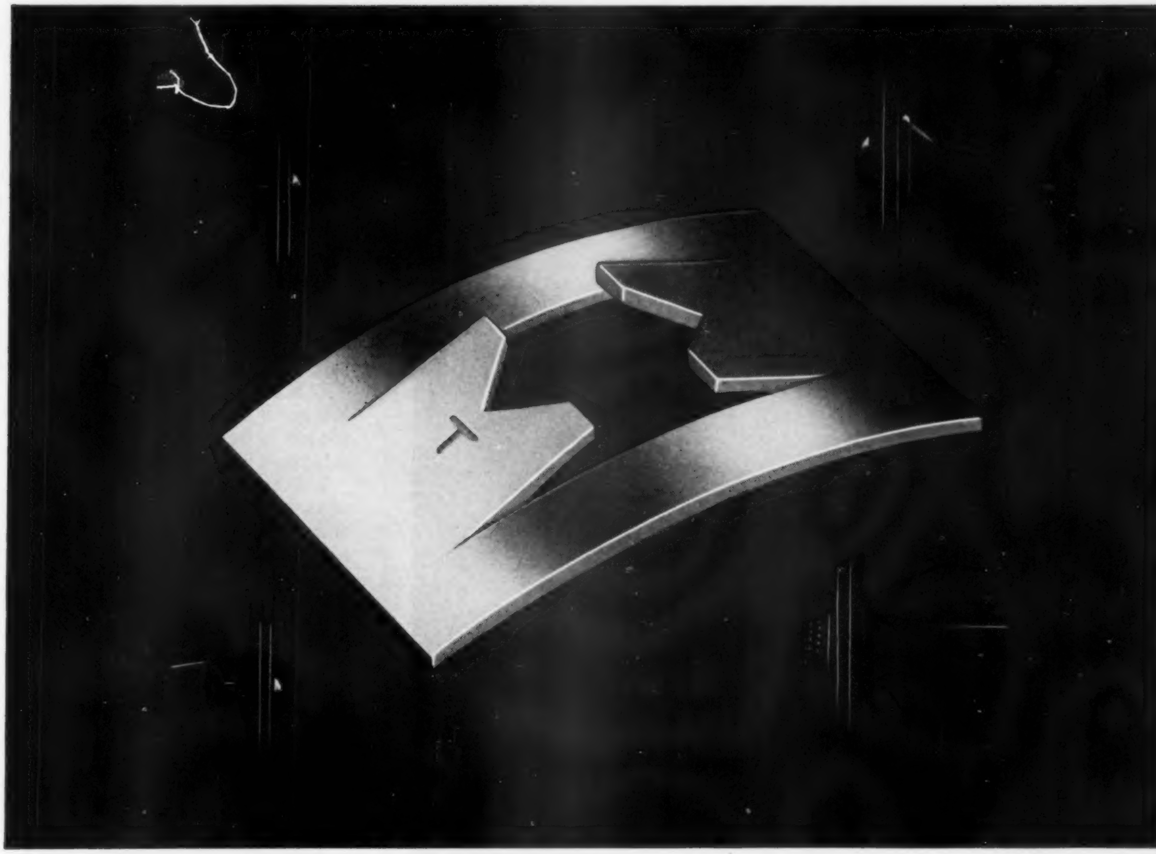
A recent literature survey by Harold Stromberg of the University of California reveals that only aluminum of a number of metals investigated resists hydrogen embrittlement under various conditions of temperature and pressure. Also, the 300 series stainless steels in the severely work hardened condition have better resistance to hydrogen embrittlement than fully annealed low alloy steels.

Other conclusions drawn from the survey:

1. The 400 series stainless steels are quite susceptible to hydrogen embrittlement in the hardened condition, whereas they are resistant in the soft state. Type 420 has about the same resistance to hydrogen embrittlement as the 300 series under all conditions of temperature and pressure.

2. Chromium steel (12%) in the Rockwell hardness range of C43 to C46 is extremely susceptible to hydrogen embrittlement, but it shows no hydrogen embrittlement in the Rockwell hardness range of C23 to C25.

3. Apparently certain types of coatings and oxide films, such as cadmium vapor coatings and chro-



Another Tinnerman Original...

Tinnerman Push-On **SPEED NUTS**®
fasten with a "bite" that can't shake loose

In a split-second, this low-cost Tinnerman Push-On SPEED NUT arches its spring-steel back, then bites hard to make a positive attachment on unthreaded studs, rivets, tubing, nails, jewels, small housings.

Application is easy—finger pressure starts it; a push with a simple hand tool locks it under live spring tension. No threads to worry about, no spot welding, no riveting, no special inserts, bushings or washers necessary. Elimination of extra parts and assembly operations may save you up to 50% or more in fastening costs.

Push-On SPEED NUTS lock on everything from thermoplastics to die-cast, chrome-plated steel. Hundreds of variations to fit any shape or size stud —from very small diameters to larger rectangular shapes. Some Push-Ons have "caps" that cover exposed shaft, axle or stud ends.

Check Sweet's Product Design File, section 8-T. Or look under "Fasteners" in the Yellow Pages and call your Tinnerman representative for complete information and samples. Or write to:

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CANADA: Dominion Fasteners Ltd., Hamilton, Ontario. GREAT BRITAIN: Simmonds Aerocessories Ltd., Treforest, Wales. FRANCE: Simmonds S. A., 3 rue Salomon de Rothschild, Suresnes (Seine). GERMANY: Mecano-Bundy GmbH, Heidelberg.

For more information, turn to Reader Service card, circle No. 475

For more information, turn to Reader Service card, circle No. 373

What's new IN MATERIALS

mium oxide films, can temporarily keep hydrogen from penetrating into metal and prevent loss of ductility. However, such surface coatings are probably not effective for long-time exposure to hydrogen.

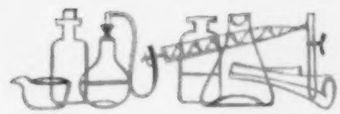
4. Nickel and nickel-base alloys are susceptible to hydrogen embrittlement both at room and high temperatures.

5. Titanium and titanium alloys in the alpha-beta condition are moderately susceptible to hydrogen embrittlement. However, in the beta condition they are virtually unaffected.

6. Copper and copper alloys, including beryllium copper alloys in

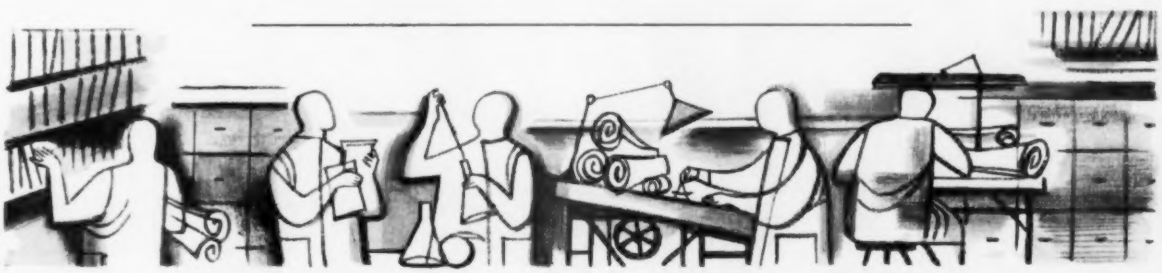
Picker X-Ray Corp.

Inspecting thick steel parts —The large stainless steel casting shown here is being prepared for radiographing with what is claimed to be the highest capacity radioisotope machine ever installed in the United States. The machine uses tiny wafers of cobalt-60 for its radiation source, and is capable of handling a radiation source of 1500 curies. According to the producer, the machine can radiograph steel castings, valves and fittings in thicknesses up to 12 in. A radiograph is a shadow picture of the internal state of the metal, and a flaw such as a void or crack will show up on the film as a proportionately denser shadow. The unit, manufactured by Picker X-Ray Corp., is now in use at Cooper Alloy Corp., Hillside, N. J.



Hundreds of custom molders of plastics have no research and development facilities . . .

Some have one or two men . . .



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- A continuing advisory service, including a Customer Service Manager assigned to live with your job through every step of production.

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the soft and hardened conditions, are virtually unaffected by high pressure hydrogen, provided oxygen content is kept low.

7. There are indications that alloying of steel with vanadium or zirconium greatly reduces susceptibility to hydrogen embrittlement.

Synthetic Felts Used for Filtration

Three synthetic fiber felts and cloths have been introduced recently for dry and wet filtering applications.

1. Nylon felt

Kranish Textile Co., 381 4th Ave., New York 16 is marketing a fleece felt woven of 100% nylon yarns. The producer says the material, designated No. 52, is suitable for filtration and other industrial applications. The nylon felt is supplied 58 in. wide and weighs 14 oz per sq yd. It sells for $2.96 per linear yd.

2. Orlon cloth

A napped, spun Orlon cloth has been developed for use in dust collectors and other dry filtration equipment that require a high rate of air flow and retention of very small particles. The cloth, called Techfab 5182E, is available from Technical Fabricators, Inc., 136 Washington Ave., Nutley, N. J. The material is said to withstand temperatures up to 250 F, and it has good resistance to solvents, oils, greases, waxes and mineral acids. The developer says free air flows through the fabric at a rate of 40 to 45 cu ft/min/sq ft at ½ in. H_2O.

3. Dacron-Orlon felt

A nonwoven felt made from Dacron, Orlon and other synthetic fibers is now commercially available from Troy Blanket Mills, 200 Madison Ave., New York City. Chief characteristics of the felt: 1) high tensile strength—up to 1500 psi, depending on the fiber, 2) good resistance to most acids and alkalis, and 3) good resistance to abrasion and moisture. According to the producer, the nonwoven synthetic felt can be used continuously at temperatures up to 400 F.

The synthetic felt, called Troyfelt,

is recommended as a padding, packing, filtering and lining material; as an insulation against sound and vibration; and for oil wick.

Tungsten Alloys for Metal Powder Parts

Improved tungsten metal powder parts are foreseen with the development of two new tungsten alloys. They are:

1. A tungsten-rhenium composition. Addition of 30 to 50% rhenium to tungsten lowers the transition temperature and aids in the working of the metal.
2. A 70 tantalum-30% tungsten alloy prepared from pre-alloyed powder that is workable at room temperature.

Powder metallurgy techniques are used to prepare tungsten ingots, and ingots as large as 3 in. in dia have been arc melted using the consumable electrode process, according to Fansteel Metallurgical Corp., North Chicago, Ill. Hydrostatic pressing, slip casting and powder spraying, each followed by a sintering treatment, are developments now being considered in the design of large tungsten parts.

Full density (19.3 gm per cu cm) is never achieved commercially in pressed and sintered tungsten powder, according to Fansteel. Densities in the range of 90 to 94% of theoretical are obtained by sintering in the range of 5070 to 5620 F. Subsequent working of the sintered product is necessary to achieve full density.

A high density sintered alloy (18.5 gm per cu cm) is commercially available that can be sintered at lower temperatures and does not require working after sintering. With as little as 1% nickel content, the alloy can be pressed and sintered at 2900 F and finish machined to

For more information, turn to Reader Service card, circle No. 506

close tolerances. After sintering the alloy has a melting point of approximately 5072 F, which may be high enough to make it usable for some rocket components. The alloy should also be considered for shielding applications since the method of fabrication makes larger parts feasible. (For information on other methods of fabricating tungsten, see article on p 74 in this issue.)

Nylon Pressure Tubing Usable up to 300 F

A flexible nylon tubing can be used continuously in an oxidizing atmosphere at temperatures up to 225 F and intermittently up to 300 F. The tubing, called Grade TR, has a life expectancy of two to five years in water at temperatures as high as 150 F. It is recommended for lubrication, hydraulic, pneumatic, fuel, solvent, beverage and instrumentation lines. The nylon tubing is available from Polymer Corp. of Pa., 2140 Fairmont Ave., Reading, Pa. Grade TR nylon tubing is supplied in diameters of 1/8, 3/16, 1/4, 5/16 and 3/8 in.

Colored Silicones for Potting, Encapsulating

Two colored silicone rubber compounds have been developed for color coding potted and encapsulated electronic parts. One, called RTV-40, is supplied white for coloring by the user; the other, called PA-407, is supplied in a variety of colors and white.

1. RTV-40

This silicone rubber is supplied as a solvent-free paste which cures to a tough silicone rubber at room temperature after the addition of a curing agent. It was developed by General Electric Co., Silicone Products Dept., Waterford, N. Y. Accord-

PROPERTIES OF RTV-40

Tensile Strength, psi	550
Elongation, %	150
Tear Strength (Die B), lb/in.	30
Durometer Hardness	A55

Casting research on 17-4PH increases elongation 10%... costs Cannon-Muskegon customers nothing ¶ Cannon-Muskegon research has developed certain procedures for investment casting of 17-4PH that assure, consistently, the high level of properties which this alloy is capable of producing. ¶ Casting test bars in a keel block arrangement as shown here—rather than an end-gated arrangement—is one of them. Special recommendations on aging time and temperature are another. ¶ Further, Cannon-Muskegon research has demonstrated the necessity of stricter limits to provide a balanced chemistry and prevent harmful effects induced by too high or too low a content of certain elements. Keeping within these limits and following Cannon-Muskegon recommendations assures investment casters of consistently obtaining optimum performance from this fine alloy. ¶ We invite you to write for a free copy of the ICI Technical Research Report, "The Effect of Aging Time and Temperature on the Mechanical Properties of Investment Cast 17-4PH."

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For more information, turn to Reader Service card, circle No. 509

What's new IN MATERIALS


Plastic Associates
***Electronic parts** are color coded by dipping them into colored silicone rubber paste.*

ing to GE, RTV-40 makes an excellent material for sealing, calking, potting and encapsulating electronic assemblies. It can also be used as a flexible mold material for casting epoxy resins or for making prototype rubber parts.

2. PA-407

Supplied in a pre-metered kit containing a color-mixed compound and a catalyst, PA-407 cures to a tough, resilient silicone rubber at room temperature. The compound has good electrical properties under humid conditions. It was developed by Plastic Associates, 185 Mountain Rd., Laguna Beach, Calif.

Boron Stainless Steel Used in Reactor Parts

An austenitic stainless steel containing boron has been introduced by Carpenter Steel Co., Reading, Pa. for use as control rods and shields in nuclear reactors. The new material, designated type 304L, is avail-

PROPERTIES OF 304L[a]

Tensile Strength, psi	100,000
Yield Strength (0.2% offset), psi	50,000
Elongation (in 2 in.), %	10
Reduction in Area, %	10
Impact Str (V-notch Charpy), ft-lb	7.5
Rockwell Hardness	B98

[a]Containing 1.8% boron; annealed at 1900 F and water quenched.

able in two boron levels, 2% and 1.5% minimum. The alloy is currently manufactured in round and flat bars.

Thermoelectric Used from 850 to 1500 F

A new thermoelectric material, said to be the most efficient of its type (semiconductor) yet discovered, performs well at temperatures from 850 to 1500 F.

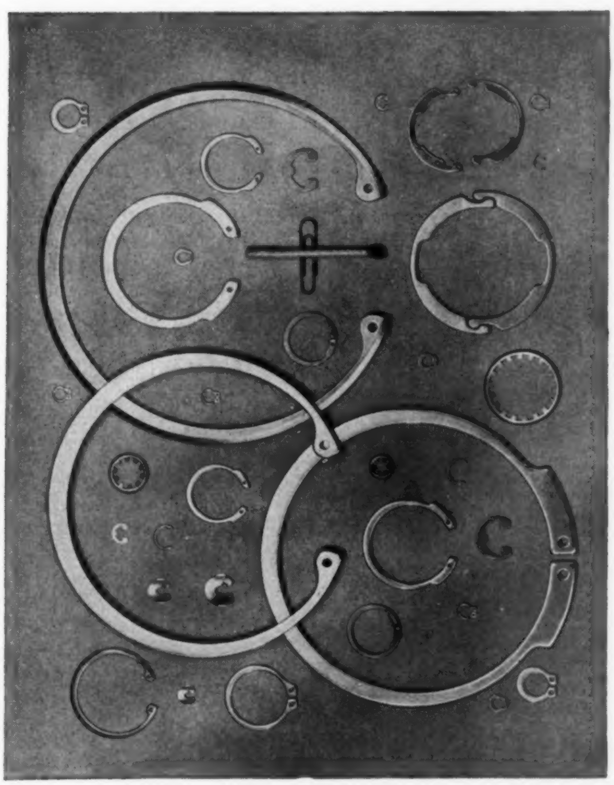
The semiconductor material is expected to find use in thermoelectric devices operating at temperatures well above those previously considered practical. The material is a three-element compound known as indium arsenide phosphide; it is prepared by chemically combining high purity indium with equally pure arsenic and phosphorus. It was developed by Westinghouse Electric

Glass-coated ductile iron—The glass-coated ductile iron fittings shown here are said to be 2½ to 3 times stronger than presently available glass-coated fittings made of gray iron. The tensile strength of ductile iron is virtually unaffected by the high temperature firing used in the glassing process, whereas the tensile strength of gray iron is reduced by as much as 25%. Glass-coated ductile iron has good resistance to acids, except hydrofluoric, at temperatures up to 350 F, and good resistance to most alkalis at moderate temperatures. Standard glass-coated fittings made of ductile iron will be available for July delivery from Pfaudler Co., Div. of Pfaudler Permutit Inc., 1088 West Ave., Rochester 3, N. Y.

Retaining rings in a multitude of shapes and sizes are speeding assembly and cutting production costs of a host of industrial and consumer products. A leading manufacturer of these efficiency-improving parts recently greatly expanded the range of applications for retaining rings by adding a complete line of standard and special rings of Armco PH 15-7 Mo Stainless Steel.

By taking advantage of the ultra-high strength, spring properties, good corrosion resistance and high temperature properties of this unique metal, they now produce retaining rings with performance characteristics heretofore unobtainable at reasonable cost. Their new PH 15-7 Mo rings have the necessary combination of strength and durability for economical service in chemical, food and beverage machinery; aircraft and missile components; units for nuclear reactors, appliances; marine equipment; and other applications subject to severe service conditions.

How Armco PH 15-7 Mo Stainless Steel Helped make a good product better



Simplifies Ring Production

The simple heat treatment and good fabricating characteristics of Armco PH 15-7 Mo facilitate manufacturing operations. All types and sizes of rings can be produced because PH 15-7 Mo is available in sheets, strip, plates, bars and wire, including special cold drawn shapes that completely eliminate some production steps.

Consider the design and production advantages *you* can achieve with Armco PH 15-7 Mo or one of its companion grades of precipitation-hardening stainless steel, Armco 17-4 PH or 17-7 PH. Let us send you complete information. Just fill out and mail the coupon.

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Send me complete information on your special Armco Precipitation-Hardening Stainless Steels. We are considering them for__________
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For more information, turn to Reader Service card, circle No. 532

Corp., Box 2278, Pittsburgh 30.

Thermoelectric materials convert the heat of a burning fuel or other high temperature source of heat directly into electricity. The materials fall into three main categories: semiconductors, metallic compositions and mixed valence compounds. Thermoelectric materials show promise for power generation and refrigeration. (For more information on thermoelectric materials, see M/DE, Mar '58, p 118 and Nov '58, p 158.)

Rigid Urethane Foam Is Fire Resistant

Rigid, fire resistant polyurethane foams can now be made from a new series of polyester resins with fire resistance properties built right into the resin. Previously, polyurethane foams were made fire resistant by using additives in the foam formulation.

The resins are available from Hooker Chemical Co., Products Development Dept., Box 344, Niagara Falls, N. Y. The first resin in the series, Hetrofoam 10, sells for 75¢ per lb in carload lots.

Potential uses

Possible uses suggested by the company for foams made of the resins include:

1. Thermal insulations for use at temperatures up to 350 F.
2. Commercial and military boats.
3. Cores for special honeycomb structures such as fire doors, refrigerator doors and transportation equipment.
4. Radomes.
5. Potting and encapsulating compounds for electrical parts where fire resistance would be of advantage.

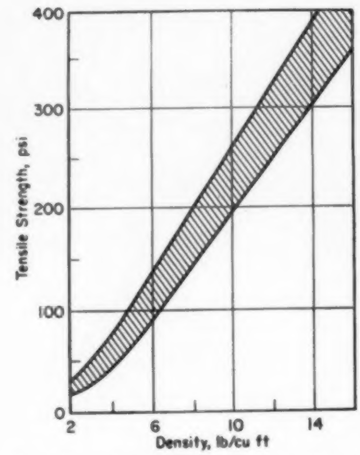
Properties

Fire resistance—A polyurethane foam with a density of 2.5 lb per cu ft retains 50% of its room tem-

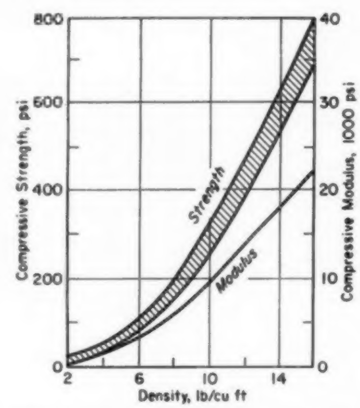
SOURCES of most engineering materials can be found in the second edition of M/DE's *Materials Selector* reference issue, published last October. Properties of all materials are also given.

For more information, circle No. 502 ➤

What's new IN MATERIALS



Tensile strength *of polyurethane foam at various densities.*



Compressive strength *and compressive modulus of fire resistant foam at various densities.*

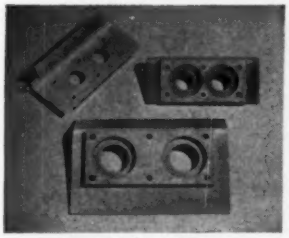
perature compressive strength at approximately 260 F.

Moisture resistance—Foam made of the resin does not shrink or lose its strength after aging 42 days at 158 F and 100% RH.

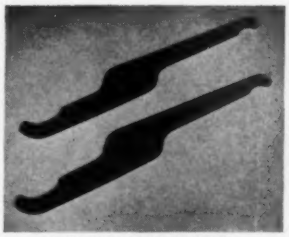
Heat resistance—Room temperature tests show that foam aged 84 days at 194 F does not shrink or lose its compressive, tensile or flexural strengths.

Weather resistance—A glass-reinforced honeycomb core made of the resin does not change in dimensions, adhesive strength or tensile strength after outdoor exposure for two years.

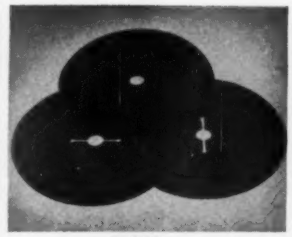
Solvent resistance—Foams made



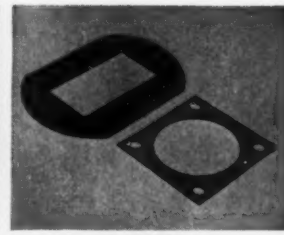
BAFFLE PLATES



FUSE-PULLER PARTS



DISCS



GASKETS

FORMED INSULATOR

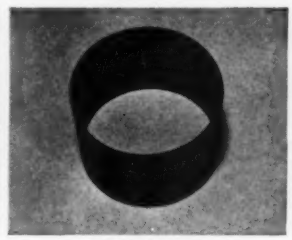
SCREW

FORMED CLAMPS

INSULATING BUSHING

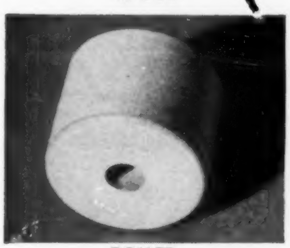
SPOOL

CABLE GRIP



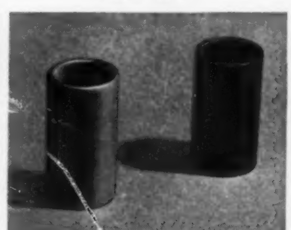
BUSHING

FORMED INSULATORS



ROLLER

NUMBER TAG



BINDER BUSHINGS

GOLF-CLUB FACINGS

FIBRE – the low-cost insulation of 1001 uses

Look what Diamond Vulcanized Fibre can do for you! And look what *you* or CDF can do with *it!*

If you can keep high-quality fibre clear of its worst enemy—moisture—you have the best economical insulating material you'd ever want for high arc-resistance, non-tracking, and long-time dielectric strength.

UNIQUE PROPERTIES • The high tensile, flexural, and impact strengths, the easy workability (ideal for screw machines), the Rockwell hardness (to R80), the light weight (half that of aluminum), the low cost, and the excellent electrical characteristics (arc-resistance up to 150 sec.) of CDF Fibre make it a highly attractive basic insulation for cost-conscious designers and purchasing men. Put these properties to work in your product.

FABRICATION FACILITIES • CDF has excellent and extensive facilities and know-how for turning out finished Diamond Vulcanized Fibre parts—better and more economically than you can do it yourself. We meet *your* specifications and *your* production schedules, and save you time and money in the bargain.

Send us your print or your problem, and we'll return technical literature. For the phone number of the CDF sales engineer nearest you, see Sweet's, Electronics Buyers' Guide, and other directories.

CDF makes Di-Clad printed-circuit laminates, Diamond Vulcanized Fibre, CDF products of Teflon, flexible insulating tapes, Dilecto laminated plastics, Celoron molded products, Micabond mica products, Spiral Tubing, Vulcoid.

CONTINENTAL-DIAMOND FIBRE

A SUBSIDIARY OF THE *Budd* COMPANY • NEWARK 25, DEL.

For more information, turn to Reader Service card, circle No. 491

from Hetrofoam 10 are said to resist most solvents. Tests show a foam withstands two weeks' immersion in gasoline and No. 2 fuel oil without dimensional change or loss of strength.

Cork-Silicone Gaskets for High Temperatures

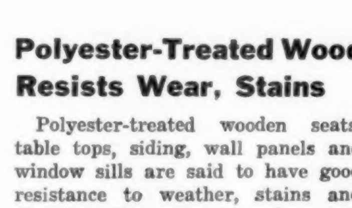
A cork and silicone rubber gasketing material has been developed for high temperature sealing applications. The new material, called LC-800, is available from Armstrong Cork Co., Industrial Div., Lancaster, Pa. The cork-silicone rubber compound can be fabricated into lathe-cut rings, mats, sheets and die-cut parts.

Polyester-Treated Wood Resists Wear, Stains

Polyester-treated wooden seats, table tops, siding, wall panels and window sills are said to have good resistance to weather, stains and abrasion. The treated wooden parts are now available from Hartglas Co., 1302 Expressway Dr., Toledo 8, Ohio.

As shown in the accompanying diagram, surfaces of treated parts are composed of a decorative layer sandwiched between two glass fiber layers. Polyester resin, applied under heat and a vacuum, penetrates the glass fiber and decorative surface layers and 0.005 to 0.015 in. into the wood.

A polyester-treated wooden specimen, cut open to expose both end and side grain, was totally immersed in water for 24 hr and then dried in



Penetration *of polyester resin into surface layers and wood is shown by this schematic diagram.* (Allied Chemical Corp.)

Chicago Molded plastic licks corrosion problem...cuts cost, too

This molded plastic part is an important component of a deep-well pump. For years it was made of brass and subject to the abrasive and corrosive effects of impure waters. How could it be improved? Would a plastic resist this wear and absorb little or no water? That's when the manufacturer came to Chicago Molded. Our answer—to injection mold it in linear polyethylene. Cost—only a small fraction that of brass, with finishing eliminated. We had an idea, too, that the smooth surface of the part would improve the efficiency of the pump. It worked just that way, and it's good business at several thousand parts a year. We're equally experienced at compression and transfer molding . . . practically every known plastic. Because of this we can make unbiased recommendations . . . provide the material and method that will assure utmost value to you. Perhaps custom molded plastics can solve your problem. Want to discuss it? Call or write . . . no obligation.

CHICAGO MOLDED
PRODUCTS CORPORATION
1026 North Kolmar Avenue, Chicago 51, Illinois

For more information, turn to Reader Service card, circle No. 488

What's new IN MATERIALS

Allied Chemical Corp.

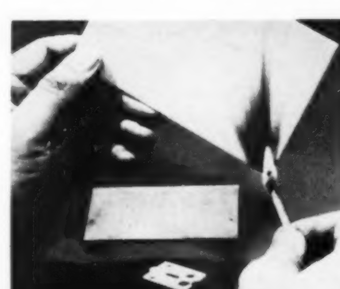
Impact resistance *of treated wood is demonstrated when ½-lb bottle dropped on its rim from 20 in. fails to make a dent in the surface.*

a heated building for 24 hr. The cycle was continued, and after five months no sign of film failure or delamination had appeared on the treated wooden specimen.

Paper-Base Laminates Are Fire Resistant

Four new fire resistant, paper-base plastics laminates have been introduced during the last few months for electrical applications. Two fire resistant laminates are impregnated with epoxy resins and two with phenolic resins.

(continued on p 165)



Paper-epoxy laminate *developed by Continental-Diamond Fibre Corp. quickly extinguishes flame.*

For more information, turn to Reader Service card, circle No. 384

What's new IN MATERIALS

PROPERTIES OF EP-37

PHYSICAL PROPERTIES	
Specific Gravity	1.45
Flammability	Self-extinguishing
Water Absorption (24 hr), %	
1/16 In. Thick	0.33
1/8 In. Thick	0.21
MECHANICAL PROPERTIES	
Tensile Strength, psi	20,000
Impact Str (Izod notched), ft-lb/in.	0.55
Compr Str (flatwise), psi	28,000
Flex Str (flatwise), psi	26,000
Bond Strength, psi	1200
ELECTRICAL PROPERTIES	
Dielec Str (step-by-step), v/mil	640
Dielec Str (par., step-by-step, 1/16 in. thick), kv	
Cond A	80
Cond D48/50	70
Dielectric Constant (1 mc)	
Cond A	4.7
Cond D48/50	5.3
Dissipation Factor (1 mc)	
Cond A	0.032
Cond D48/50	0.041

PROPERTIES OF DILECTO XXXP-31EFR

PHYSICAL PROPERTIES	
Max Cont Operating Temp, F	248
Flammability	Self-extinguishing
Water Absorption (24 hr), %	0.35
MECHANICAL PROPERTIES	
Tensile Strength, psi	
Lengthwise	12,000
Crosswise	9500
Flexural Strength, psi	
Lengthwise	23,000
Crosswise	19,000
Compr Str (flatwise), psi	30,000
Rockwell Hardness	M100
ELECTRICAL PROPERTIES	
Insulation Res, megohms	1 x 10^6
Dielec Str (perp, short-time), v/mil	650
Arc Resistance, sec	6
Surface Resistance, megohms	100,000
Dielectric Constant (1 mc)	4.1
Dissipation Factor (1 mc)	0.031

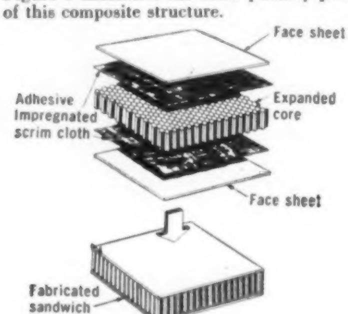
1. Paper-epoxy laminates

Formica Corp., 4614 Spring Grove Ave., Cincinnati 32, Ohio, has introduced a flame retardant, copper-clad paper-epoxy laminate. The material, called EP-37, is self-extinguishing. It does not blister when exposed 1 hr at 300 F or when immersed 15 sec in a 500 F solder bath. It has good dimensional stability, excellent insulation resistance and good punchability. A new adhesive secures the

DESIGNERS' CHOICE: Materials for HONEYCOMB SANDWICH STRUCTURES

Honeycomb sandwich structures are composed of thin, high strength facings integrally bonded to light weight core material. The selection of materials to be used in such a structure is of primary importance in arriving at a satisfactory design providing optimum performance.

Figure 1 illustrates the three primary parts of this composite structure.



Facing Selection

Generally the facings in a sandwich structure are selected in order to provide the highest compressive strength-to-weight ratio economically available in the size range under consideration. Examples of facings on successful sandwich applications are carbon steel in thicknesses of .030 to .050 for heavy duty flooring applications; aluminum alloy 7075 T6 in thicknesses of .010 to .093 for flooring and highly stressed panel applications, and porcelain enamel steel in 14 to 24 gauge for exterior curtain wall applications. Other special applications have dictated the use of high temperature reinforced fiber glass-plastic skins, stainless steel skins, cement asbestos board skins and similar materials. In every case, the facing selection must meet the multiple criteria of economy, structural efficiency, and process compatibility.

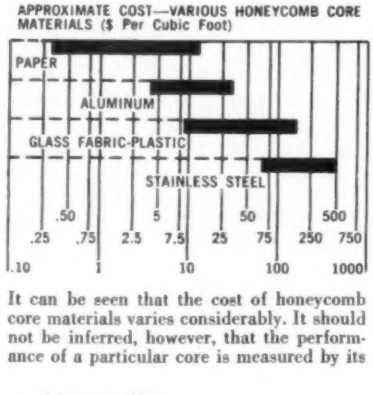
Adhesive Selection

There are now available to designers a number of adhesive systems for attaching honeycomb core materials to high strength facings. Most high strength structural adhesives are based on various combinations of thermosetting resins which provide structural integrity throughout the environmental conditions encountered. For lightly loaded panels subject to less exacting environmental conditions there are a number of adhesives based on thermoplastic or elastomeric resins, some of which permit very economical sandwich fabrication.

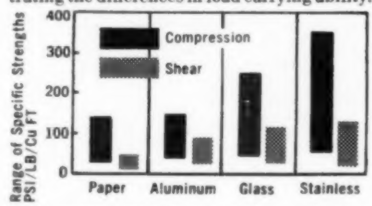
Honeycomb Core Selection

Core materials are selected on the basis of structural performance, environmental requirements, and economy.

APPROXIMATE COST—VARIOUS HONEYCOMB CORE MATERIALS ($ Per Cubic Foot)



It can be seen that the cost of honeycomb core materials varies considerably. It should not be inferred, however, that the performance of a particular core is measured by its cost. Figure 3 indicates the specific strength of the same honeycomb core materials illustrating the differences in load carrying ability.



With proper selection of facing, adhesives and honeycomb core, the designer can achieve optimum structural performance with minimum weight. For example, a beam of steel plate weighing 68.6 lbs. can be replaced by a structural honeycomb sandwich beam of 7.8 lbs. with the same deflection and strength.

The design opportunities for honeycomb sandwich structures are apparent.

Since World War II designers of air and space craft have made ever-increasing use of honeycomb in a great variety of structural and non-structural applications. Honeycomb can be made from almost any material available in continuous web or roll form, e.g., aluminum, glass fabric, cotton, stainless steel, paper, asbestos, titanium. In its cellular configuration, honeycomb is 97% air, 3% material.

Honeycomb has intrinsic qualities of high strength, light weight, high ratio of surface area to volume and other specific properties which depend upon the type of material used. These combinations of properties, which have given honeycomb wide application in air and space craft, offer to designers in industry generally unique opportunities in product design. In the interest of advancing this knowledge of honeycomb, Hexcel, through its research and development staff (the industry's largest), has prepared this informational series. Should you desire additional technical information or copies of others in this series, please complete the information request form on this page. Your request will receive immediate attention.

INFORMATION REQUEST

Send to Hexcel Products Inc. Dept. "M"
2332 Fourth Street, Berkeley 10, California.

NAME________________
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COMPANY________________
STREET________________
CITY________ZONE____STATE______

HEXCEL® PRODUCTS INC.
World leader in honeycomb
***Executive offices:** 2332 Fourth St., Berkeley, California*
***Plants:** Oakland and Berkeley, California; Havre de Grace, Maryland*
***Sales offices:** Inglewood, Calif.; Fort Worth, Texas; Long Island City, N. Y.* 5478

For more information, turn to Reader Service card, circle No. 434

copper cladding to the base laminate so that EP-37 offers greater resistance to plating solutions.

Dilecto XXXP-31EFR is the name given to a new XXXP flame retardant paper-epoxy laminate now commercially available from Continental-Diamond Fibre Corp., Newark, Del. The laminate is also available as copper-clad sheets (Di-Clad 31EFR). According to the developer, the material is unusually flame retardant and remains rapidly self-extinguishing after five ignitions. The laminate has good resistance to humidity, has good cold punching properties, and is much lighter than glass-epoxy laminates.

2. Paper-phenolic laminates

Good flame retardance and good self-extinguishing properties characterize a new paper-phenolic laminate introduced recently by Synthane Corp., Oaks, Pa. The laminate, designated Grade FR-1, is recommended for use in electrical applications where good mechanical properties are required.

National Vulcanized Fibre Co.,

PROPERTIES OF FR-1

Max Cont Operating Temp, F	275
Flammability, sec	
Ignition Time	120
Burning Time	30
Extinguishing Time	5
Flexural Strength, psi	
Lengthwise	15,000
Crosswise	14,000
Insulation Re. (cond D96/95), megohms	60

PROPERTIES OF XXXP-475

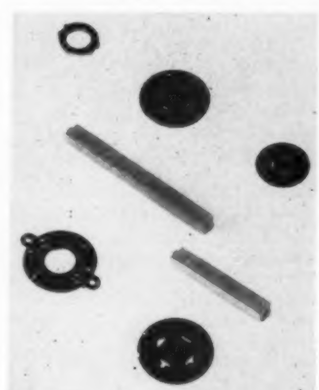
PHYSICAL PROPERTIES	
Specific Gravity	1.33
Flammability, sec	2
Water Abs (cond E1/105, then D24/23), %	
1/16 In. Thick	0.39
1/8 In. Thick	0.20
MECHANICAL PROPERTIES	
Flexural Strength, psi	15,000
Impact Str (Izod notched), ft-lb/in	0.40
Rockwell Hardness	M106
ELECTRICAL PROPERTIES	
Dielec Str (par., step-by-step, 1/8 in. thick), kv	
Cond A	63.3
Cond D48/50	45.0
Dielectric Strength (cond A), v/mil	805
Insulation Resistance, megohms	
Cond A	$>25 \times 10^5$
Cond C96/35/90	13×10^4

What's new IN MATERIALS

1059 Beech St., Wilmington 99, Del. has introduced a flame retardant paper-phenolic laminate for printed circuits. The laminate, called XXXP-475, has low moisture absorption, high insulation resistance and good punching properties. It is supplied as standard sheets and in copper-clad form. The laminate does not blister after 9-sec exposure to a 500 F solder bath.

Aluminum Nitride Resists Molten Metals

Dense, homogeneous, nonporous refractory shapes of pure aluminum nitride have excellent resistance to molten aluminum at temperatures up to 2600 F, recent research indicates. Molten iron and silicon have no effect on the material at temperatures up to 3100 F. The refractory shapes also have good resistance to temperatures over 3600 F in an atmosphere of nitrogen, and good electrical properties at tem-



Which side is up?—Taylor Fibre Co., Box 471, Norristown, Pa. is using color facings on its line of paper-base laminated plastics parts as a quick, positive way to tell one side of a laminated plastic part from the other. Parts such as the washer, capacitor plate and capacitor bases shown here can be faced in ten different color combinations. The laminate bars in the middle row have colored liners for identification.

PROPERTIES OF ALUMINUM NITRIDE

Density, lb/cu in.	0.090
Hardness (Mohs)	5
Coef of Ther Exp (32-1800 F), per °F	6.5×10^{-6}
Ther Cond (212 F), Btu/hr/sq ft/°F/ft	5.8
Volume Resistivity, ohm-cm	
900 F	2×10^{-8}
1800 F	2×10^{-5}
2700 F	3×10^{-3}

peratures up to 2700 F.

The refractory parts were made by new bonding and fabricating techniques developed recently in France.

Properties

Tests results, compiled by M. Rey and presented in the Sept '58 issue of *Silicates Industriels*, show that the refractory shapes have good thermal shock resistance and excellent resistance to most chemicals.

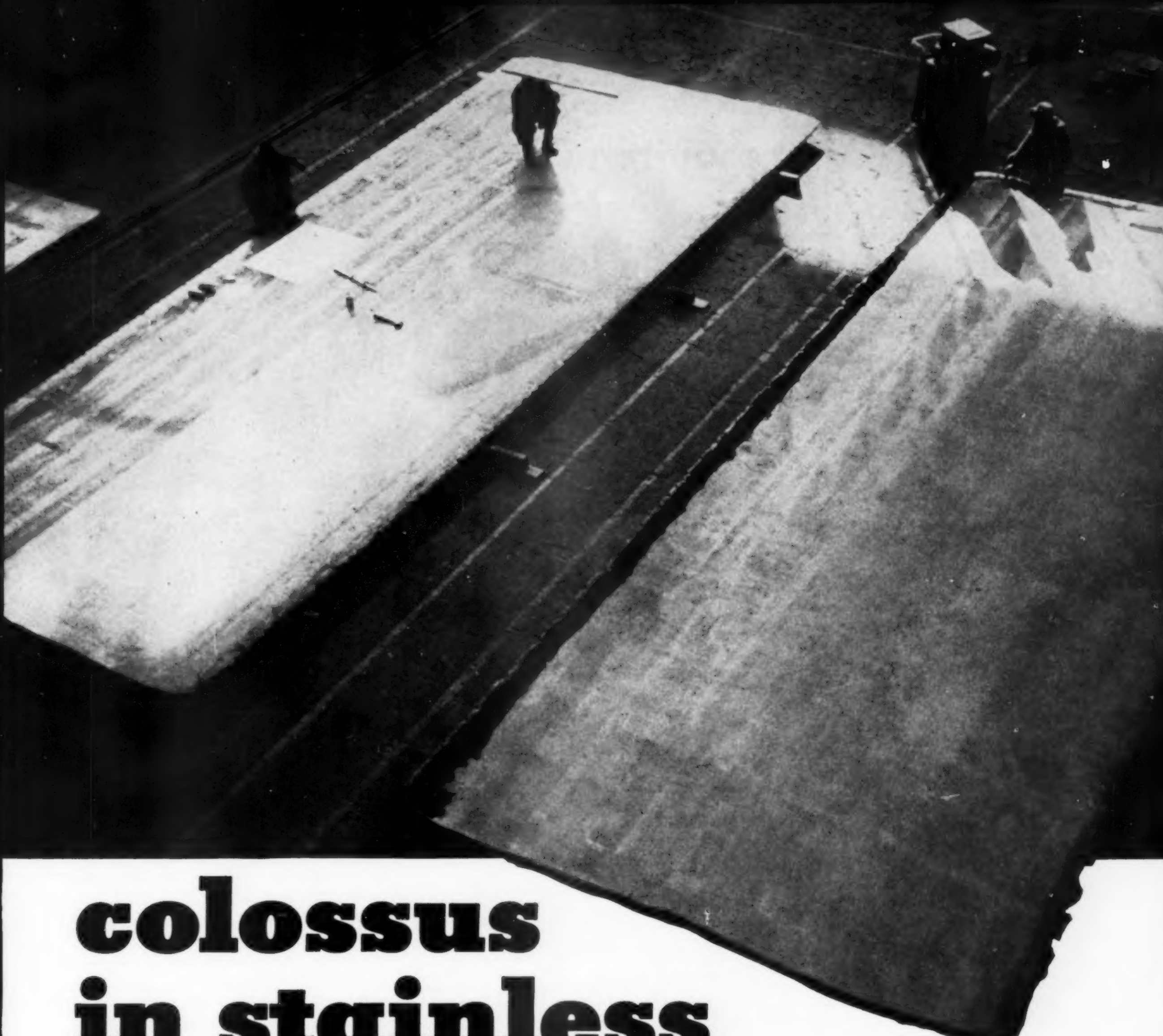
The test results, translated by B. M. Pearson, show that dry steam has no effect on the material at temperatures up to 930 F. Water causes the material to disintegrate slowly, giving off ammonia and forming hydrated alumina. Chlorine gas attacks the material at a temperature of 1100 F; air, oxygen and carbon dioxide at 1400 F; carbon at 2200 F; and carbon monoxide at 2700 F. Hydrogen gas has no effect on aluminum nitride. Alkaline glasses react with the material at a temperature of 2900 F; borosilicate glasses react at 3000 F.

How parts are made

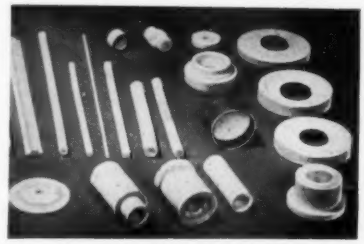
Refractory shapes are made by reacting finely powdered aluminum metal and a non-aqueous organic agglomerating agent with aluminum nitride crystals at 2600 F. Parts are shaped from this material in steel molds heated to about 180 F under a pressure of 2 or 3 tsi, hardened at 840 F in an oxidizing atmosphere, and fired at 2500 F in a nitrogen atmosphere.

Beryllium Oxide Parts Usable up to 4600 F

Fabricated, fired and extruded shapes of beryllium oxide, now commercially available, can be used at temperatures up to 4600 F without damage. Introduced by National



What's new IN MATERIALS



***Electronic parts,** as well as nuclear reactor and missile parts, are some potential applications for beryllium oxide shapes.*

Beryllia Corp., 4501 Dell Ave., N. Bergen, N. J., the shapes are called Berlox.

Potential uses include waveguide windows, pyrometer sleeves, electron tube spacers, heat exchangers and nuclear reactor parts.

Vinyl Fluoride Film Resists Weathering

Limited production has begun on a transparent polyvinyl fluoride film that is said to have outstanding weathering characteristics together with excellent chemical resistance and good mechanical strength. The product was first announced about a year ago by E. I. du Pont de Nemours & Co., Inc., Film Dept., Wilmington 98, Del. (see M/DE, July '58, p 136).

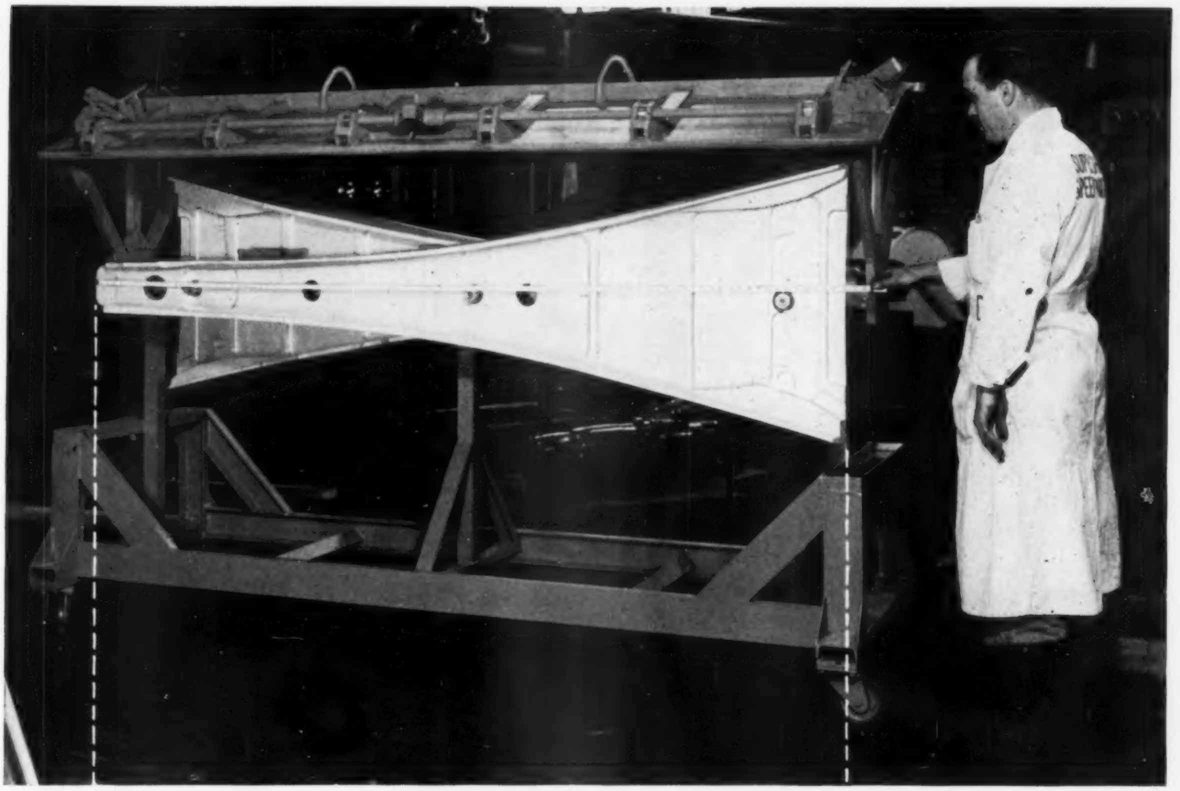
The material, called Type R film, is supplied in widths from 42 to 50 in., and in thicknesses from 1 to 4 mils. Introductory price is $5 per lb.

Properties and uses

Specimens of unsupported film have not embrittled or discolored after 10 years' exposure in Florida, and researchers predict that the film applied as a finish on laminates will have a useful life more than double that of unsupported film.

The plastics film has excellent resistance to such highly reactive chemicals as sulfuric acid, sodium hydroxide and carbon tetrachloride. The new film is non-plasticized, and is usable in products exposed to temperatures from –100 to 250 F.

Type R film appears promising for glazing applications because of its toughness and unusually long outdoor life. It can be vacuum metal-



93"

Can parts this long be barrel finished?

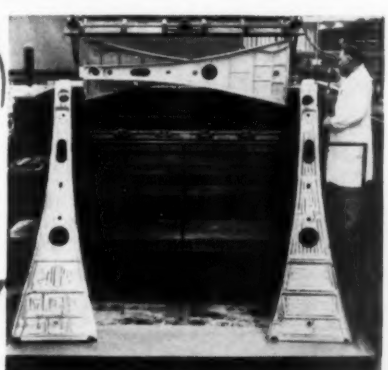
ALMCO Supersheen System — SUPERIOR MACHINES AND METHODS FOR FINER BARREL FINISHING

YES! With ALMCO's efficient, versatile barrel finishing equipment, the 93 inch wing spar above was finished in a two hour time cycle. Thirty inches long at the wide end and 8 inches thick, the spars are finished two at a time in a special ALMCO unit at McDonnell Aircraft Corp., St. Louis, Missouri. Previous hand methods required many additional hours of finishing time and it was difficult to maintain uniformity of the parts.

These aircraft wing spars are barrel finished to blend in radii and improve micro-inch finish on other surfaces through use of ALMCO Supersheen media and burnishing compounds. All surfaces receive the same treatment—rejects due to imperfect finishing are eliminated. Tremendous labor savings are made by using ALMCO's modern barrel finishing methods.

ALMCO's modern machines and methods—the Supersheen System—may help you achieve vital costs savings too. At ALMCO you receive trained counsel for your finishing problems . . . *free* sample processing in ALMCO's modern labs . . . skilled guidance in selecting the proper standard or custom-designed ALMCO machines and methods. Write today on your letterhead asking for an ALMCO sales engineer to call. Or send parts direct to ALMCO's lab with specs required.

Note "machining ridges" on foreground spars, prior to Almco Barrel Finishing. Supersheen Aluminum Oxide chips with Almco #10 compound are used in 2 hour finishing cycle.



NEWS ABOUT ALMCO'S NEW PRODUCTS!

New brochures now ready on Almco spindle machine, Vibrasheen, other cost saving units. Price list on Almco compounds and media included. Send for your Almco Album of New Products today!

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For more information, turn to Reader Service card, circle No. 523

***Plywood** laminated with vinyl fluoride film (left) has not embrittled or discolored after 3000-hr exposure in a Weatherometer. Painted wood specimen (right) cracks and peels after 506-hr exposure in the same machine.*

lized and thermoformed, and can be laminated to plastics, metals and other materials. The film has excellent dimensional stability and mechanical support at processing temperatures as high as 330 F when laminated to reinforced plastics.

As a dielectric, Type R film offers a unique combination of properties, including a dielectric constant of 7.5 at 68 F and 60 cps, good resistance to thermal degradation, and high dielectric strength.

Other uses contemplated for the film include industrial and decorative tapes, signs and decals for outdoor applications.

Polyethylene Foam Is Lightweight, Flexible

A flexible, low density polyethylene foam is being marketed in limited quantities by Dow Chemical Co., Midland, Mich. Density of the material is about 2 lb per cu ft, or 30 times lighter than water. The foam is available in 9-ft lengths in round stock, flattened ovals and untrimmed planks at a price of 22¢ per bd ft.

Development engineers say that flotation, fabricated parts such as gaskets, and thermal insulation appear to be among the major fields of application for the material. Early

. . . economical alternative for solid and clad metals and alloys

Kanigen®

Stainless Steel Reactor Tube Bundle—
Inside of tubes, outside of tube sheet and hub Kanigen plated to reduce the danger of stress corrosion cracking.

KANIGEN. General American's unique process for chemical nickel alloy plating on most metals and alloys, offers an opportunity for large savings on chemical equipment.

KANIGEN makes possible the use of inexpensive basis metals for tankage, valves and piping, storage and reaction vessels. It is particularly satisfactory for austinitic stainless steels when stress corrosion cracking is a problem.

Complex shapes that vary in size from a 20,000 gallon tank car to a tiny control valve can be given a uniform coating of the required thickness with Kanigen. Coating may be done by rack, jig or barrel methods.

You can get **KANIGEN** chemical nickel alloy plating from General American at Sharon, Pa.; East Chicago, Ind.; or Compton, Cal., and from licensees in many cities. For detailed information or technical advice, call or write. You'll find...
IT PAYS TO PLAN WITH GENERAL AMERICAN.

KANIGEN is a trademark which identifies chemical nickel coating by General American Transportation Corporation and its licensees, the product resulting therefrom and compositions produced by them for use in chemical nickel coating.

Write for Technical Bulletin #258

KANIGEN DIVISION
GENERAL AMERICAN TRANSPORTATION CORPORATION
135 South LaSalle Street • Chicago 90, Illinois

KANIGEN GENERAL AMERICAN TRADE MARK

For more information, turn to Reader Service card, circle No. 436

market development of the odorless, closed cell product has included such flotation items as water ski belts, lifebelts, boat bumpers, kickboards and marine toys.

The foam has good shock absorbing properties, low water absorption, good solvent and chemical resistance, and low moisture vapor transmission rates.

The material may be adhered to itself by the use of heat, or to other materials by the use of adhesives. It is easily fabricated with conventional woodworking or power tools.

Polyester Resin Wets Glass Fibers Quickly

A polyester resin that cures rapidly at room temperatures, wets glass fibers quickly, and resists sagging when applied to vertical surfaces has been developed by Rohm & Haas Co., Plastics Dept., Washington Sq., Philadelphia 5.

According to the producer, the reactivity of the resin, called Paraplex P-463, is such that only relatively small additions of catalyst are needed to effect complete cure. It is

Testing glass-coated steel—A technician uses a new electronic instrument to test glass continuity in a large glass-coated steel vessel. A neon light in the handle of the unit flashes on when the probe passes over areas of uncoated steel. The instrument, was developed by Pfaudler Co., Div. of Pfaudler Permutit Inc., 1091 West Ave., Rochester, N. Y.

PROPERTIES OF POLYESTER-GLASS LAMINATE[a]

Tensile Strength, psi	15,200
Flexural Strength, psi	28,200
Notched Izod Impact Str, ft-lb/in.	14
Modulus of Elasticity, 10^6 psi	10
Barcol Hardness	55

[a]Paraplex P-463 resin content 69%.

expected that the product will be used for the manufacture of glass-reinforced boat hulls and accessories.

Process for Making Glass-Plastics Parts

A continuous process for producing low cost glass-reinforced plastics parts has been developed. According to the producer, the cost of processing a glass-reinforced boat or panel (glass content of 40%) averages about 50¢ per lb of material, including labor and material costs.

The air operated machine is designed to spray 1) a continuous glass fiber without chopping it into short lengths, 2) liquid resins without introducing air, and 3) fillers such as sawdust or ground cork. The device is capable of spraying 2000 lb of material per hr.

The machine, called Spray Molder, was developed by Fiberlay, Inc., 1158 Fairview North, Seattle, Wash. It costs $3,995 or may be rented at

Spraying resin, *glass fibers and ground cork with a new continuous preforming device.*

$200 per month. (For information on another continuous preforming device, see M/DE, Apr '59, p 180.)

Heat Shrinks Tubing for Electrical Insulation

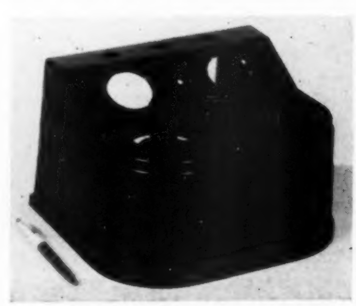
A new tubing, composition of which has not been revealed, shrinks under heat to form a tight, abrasion and chemical resistant electrical insulation for condensers, coils, bus bars, transformer leads, antennas, high voltage leads and conduit. The tubing, called No. 3042, is available from Minnesota Mining & Mfg. Co., Irvington Div., 900 Bush Ave., St. Paul 6, Minn.

Sisal-Filled Phenolics Molded into Large Parts

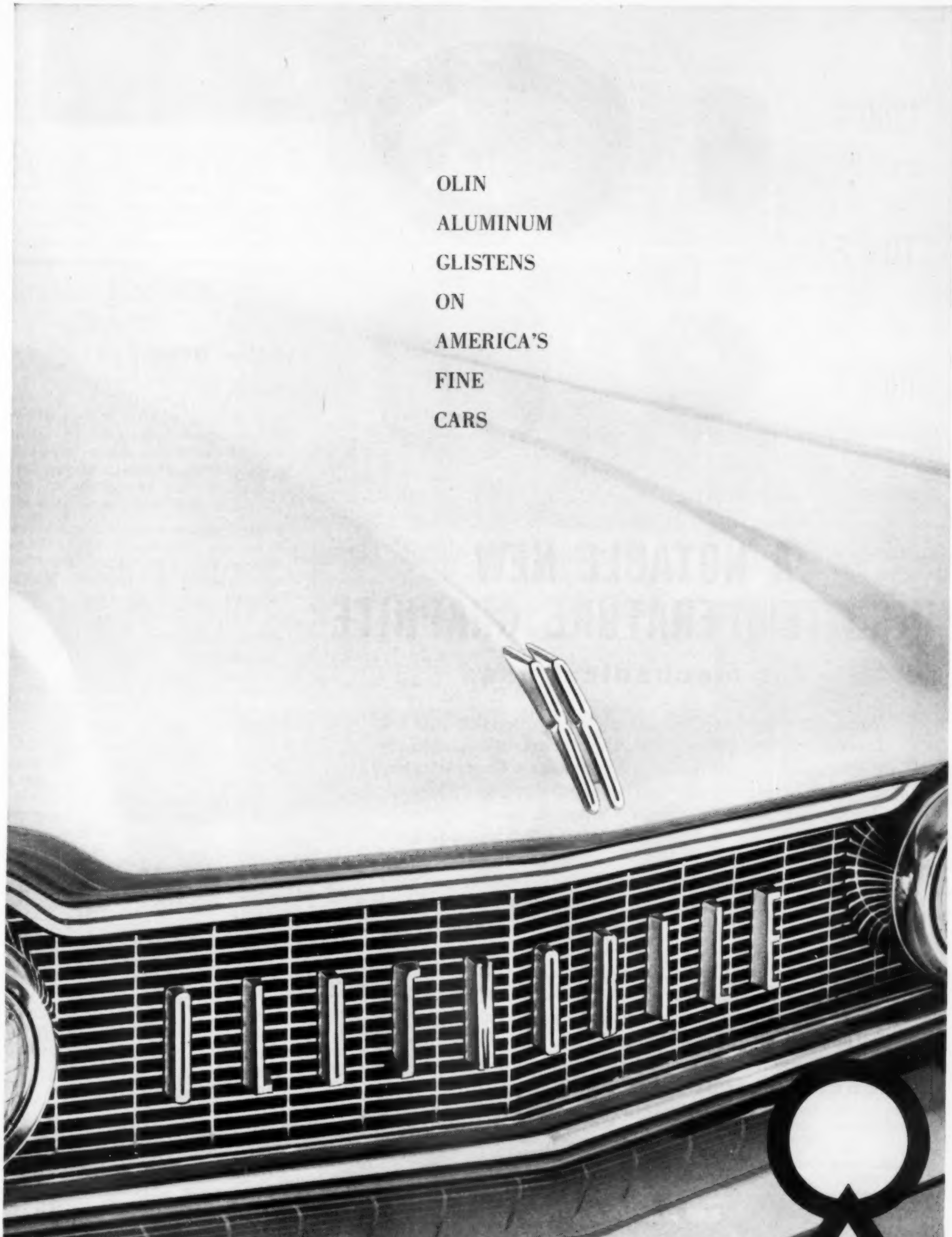
Two new sisal-filled phenolic molding compounds, RX-825 and RX-831, are recommended especially for molding into large parts, such as motor

PROPERTIES OF PHENOLIC COMPOUNDS

Type →	RX-825	RX- 31
PHYSICAL PROPERTIES		
Specific Gravity	1.42	1.42
Mold Shrinkage, in./in.	0.007	0.007
Water Absorption, %	0.7	0.7
Dielec Str (60 cps), v/mil	225	225
MECHANICAL PROPERTIES		
Izod Impact Str (notched), ft-lb/in.	0.50	1.00
Ten Str, psi	5,500	6,000
Flex Str, psi	7,500	9,000
Compr Str, psi	25,000	25,000
Heat Dist Point, F	300	300



***Typical part** molded of sisal-filled phenolic compounds.*



For more information, turn to Reader Service card, circle No. 441

housings and outlet boxes. Both compounds are now commercially available from Rogers Corp., Rogers, Conn. The two materials are medium impact, two-step compounds supplied in pellet form.

Other News . . .

Metals

▶ More than 40 sizes of deep drawn magnesium containers are now available from Zero Mfg. Co., 1121 Chestnut St., Burbank, Calif. The containers are recommended for electronic and other applications.

▶ Solid and cored aluminum bronze bars are marketed by Johnson Bronze Co., New Castle, Pa. They are supplied in standard 12½-in. lengths and in 97 sizes up to 8 in. o.d.

▶ Universal-Cyclops Steel Corp., Refractomet Div., Bridgeville, Pa. has produced what is claimed to be the largest columbium sheet ever made. The sheet, made from a 325-lb ingot, measures 0.028 x 36 x 96 in.

▶ Two nickel silver wire alloys have been introduced by Bridgeport Brass Co., 30 Grand St., Bridgeport 2, Conn. for use in screws, rivets, camera and optical parts, and costume jewelry. The alloys have good cold working properties, and are readily formed, bent or cold headed.

▶ Stainless steel pipe unions with a TFE seal are now available from Special Screw Products Co., Bedford, Ohio. The unions, called Koncentrik, are rated from 2000 to 6000 psi and are suited for use under extreme pressures or corrosive conditions.

▶ Republic Foil & Metal Mills, Inc., 55 Triangle St., Danbury, Conn. has introduced a new ultra-clean aluminum capacitor foil called Electro-Dry. The producer says the foil is free from oil films and ionizable materials.

Nonmetallics

▶ Four TFE tapes—skived, extruded unsintered, extruded sintered, and cast—are now commercially available from Joclin Mfg. Co., Wallingford, Conn. The tapes are called Fluorolin.

▶ Extruded profile shapes made from a molybdenum disulfide-filled nylon are now available from Polymer

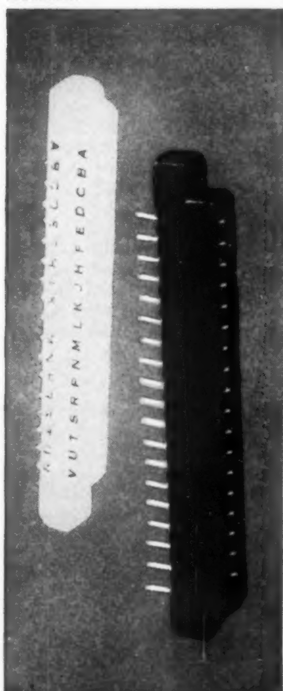
Plaskon Nylon News

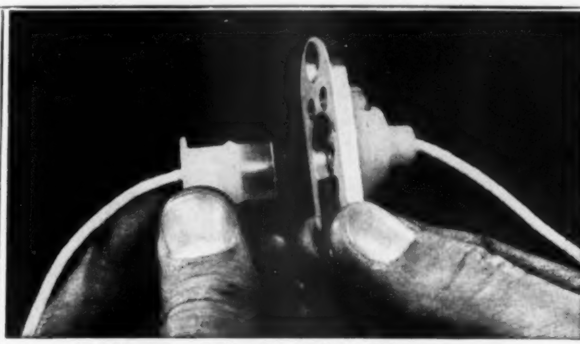
Type 6 • Nylon's Range of Applications Expands!

MORE AND MORE INDUSTRIAL AND CONSUMER PRODUCTS MAKE USE OF ITS OUTSTANDING PROPERTIES

Durable Electrical Circuits

Space Products, Long Beach, Calif., uses flexible Plaskon Nylon 8200 for circuit connectors because it produces higher uniformity of finished parts yet lowers manufacturing costs. These "Ezi-Connectors" feature beryllium contacts, with a fatigue resistance twice as great as that of spring brass or phosphor bronze. They are moisture-proof and can be easily and repeatedly inserted and removed. Available in several colors, they are lettered to permit easy assembly and identification.





Reliable Missile Fire Connector

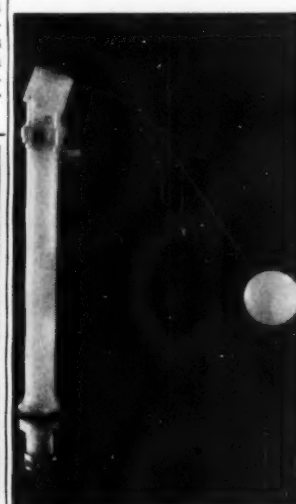
Plaskon Nylon 8200's outstanding durability, light weight and resilience are put to good use in this missile fire connector. Injection molded nylon provides excellent insulation and seal against contaminants and moisture for the connector's contacts, as well as mechanical protection for the unit itself. The manufacturer, Alden Products, Brockton, Mass., reports that Plaskon Nylon 8200 enables him to achieve the highest compactness and reliability for this vitally important missile component.

High Strength Closures

This smooth, lustrous Plaskon Nylon cap nut will not scratch, snap or tear other surfaces as do metal caps. Ideal for use in the furniture and electronics industries, the "Relok" Nut is rust-proof, antimagnetic and self-locking. Plaskon Nylon's high strength and impact resistance enable it to withstand rugged duty. The Lehigh Metal Products Company, Cambridge, Mass., supplies the "Relok" Nut in several lengths and colors.

Superior Ballcock Valve

The Hydo Valve Corporation, Austin, Texas, manufactures this ballcock toilet valve with injection molded Plaskon Nylon 8200. The valve's superior action cuts water closet fill time in half and eliminates noise and seepage. Plaskon Nylon is ideal for products of this type because of its high resistance to heat, chemicals and abrasion. Also, nylon's light weight produces a more compact unit, which can be more economically stored and shipped.



Extra Extrusion Economy! Plaskon Nylon Extrusion Compound 8205 maintains high-melt viscosity through successive regrinds. Scrap can be re-extruded several times without the slightest deterioration of basic properties.

FOR FURTHER INFORMATION OR TECHNICAL ASSISTANCE, WRITE TO OUR NYLON PRODUCT DEVELOPMENT DEPARTMENT.

PLASTICS AND COAL CHEMICALS DIVISION

40 Rector Street, New York 6, N.Y.

Allied Chemical

For more information, turn to Reader Service card, circle No. 539

Corp. of Pa., 2140 Fairmont Ave., Reading, Pa. The filled nylon profiles, called Nylatron GS, are said to reduce wear and friction on sliding surfaces. They are used for runners, conveyor tracks and sash linings.

▶ An electrically conductive polyvinyl chloride compound has been introduced by Abbey Plastics Corp., Hudson, Mass. as a possible replacement for copper braid on communications wire. Other potential uses: semiconductive electrical tape, ignition wire conductors, and impregnated paper for recording instruments.

▶ Germ resistant extruded plastics sheets are now being produced by Chicago Molded Products Corp., Campco Div., 1020 N. Kolmar Ave., Chicago. The plastics sheets are treated with a chemical additive that is said to be odorless, colorless and nontoxic.

▶ Two new grades of free-machining laminated tubing have been added to a series of paper-base laminates produced by Richardson Co., 2700 Lake St., Melrose Park, Ill. Insurok T-300 NEMA X tubing meets Mil Type PBM; Insurok T-301 NEMA XX meets Mil Type PBG.

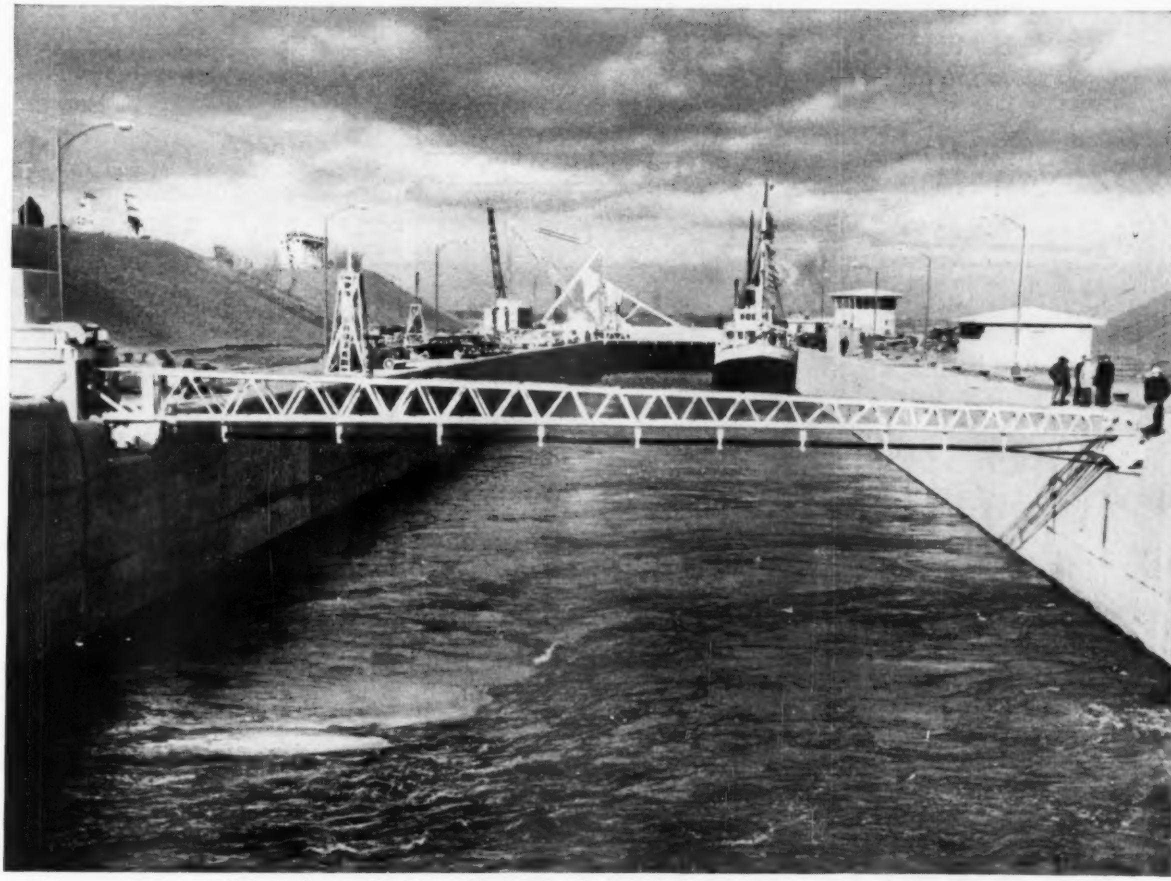
Finishes

▶ A zinc phosphate coating applied over a very thin deposit of electroplated zinc is said to retard flaking and peeling of paint on steel products. The coating is applied to steel by Kirsch Co., Metal Coating Div., White Pigeon, Mich.

▶ Entek 45 is the name given to a liquid additive for use in hot water rinses of plating systems. The additive is said to promote spot-free drying of ferrous and nonferrous metals after plating, pickling and chemical processing. It was developed by Enthone, Inc., 442 Elm St., New Haven, Conn.

▶ A line of strippable plastics coatings for temporary protection of finished surfaces has been introduced by Guard Coatings Corp., 8-05 43rd Ave., Long Island City 1, N. Y. Two classes of coatings are available: 1) fast drying solvent solutions, and 2) water dispersions.

▶ A one-coat enamel has been developed by Arco Co., 7301 Bessemer Ave., Cleveland 27, Ohio as a possible replacement for galvanized steel in outdoor air conditioning



Mammoth parts for Iroquois and other locks in St. Lawrence Seaway and Power Project depend on nickel alloy steels for prolonged service without repair.

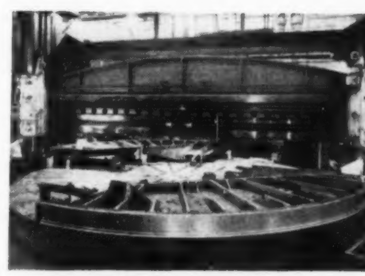
Nickel Alloy Steels help open the world's eighth sea to commerce

The opening of the St. Lawrence Seaway turns the Great Lakes into the world's eighth sea—giving us, in effect, a North American counterpart of the Mediterranean.

Man moved water and earth—even towns — to make this possible. It was a colossal job . . . and called for that kind of thinking and building.

Take some of the lock bridge construction, as an example. Cast steel track girders and segment girders for the rolling lift bridge at Iroquois Point, in the International Rapids Section, weigh as much as 14 tons. **Repairing or replacing** such monster units any time after installation would be excessively expensive. And in some locations, practically impossible. So where long life plus high strength and toughness are important considerations, castings of nickel steel are high-ranking favorites. This high strength nickel alloy steel is liberally used wherever the stresses on structural shapes are most severe and where castings are exposed to atmospheric corrosion.

Do you have a metal problem? One involving stress . . . wear . . . corrosion . . . fatigue . . . temperature extremes or other complicating factors? Talk it over with us. We — and Nickel or a Nickel Alloy — may be able to help you find the channel that leads to open water. *Registered trademark



Heavyweights. Segment girders of nickel steel for Iroquois Lock rolling lift bridge weigh 27,000 pounds apiece.

THE INTERNATIONAL NICKEL COMPANY, INC.
67 Wall Street INCO New York 5, N.Y.

INCO NICKEL

NICKEL MAKES ALLOYS PERFORM BETTER LONGER

What's new IN MATERIALS

equipment. The enamel is said to have excellent resistance to salt spray and industrial atmospheres.

▸ Nonsacrificial lead alloy anodes for impressed current cathodization have been approved by Lloyd's of London for the protection of ship hulls against corrosion, according to an article in the latest issue of *Lead* published by Lead Industries Assn., 60 E. 42nd St., New York 17.

Joining materials

▸ United Welding Service Co., Box 564, Franklin, Pa. is marketing a new aluminum solder that requires no flux. The solder is marketed in the form of wire, rod, strip and powder.

▸ Welding rod and wire made of copper alloy 835 produce high copper content welds that are sound, ductile and strong, according to the developer, Bridgeport Brass Co., 30 Grand St., Bridgeport 2, Conn. The welding rod and wire have a melting point of 1965 F.

▸ A low hydrogen nickel-manganese electrode has been developed for joining and wear surfacing manganese and plain carbon steels. It is marketed by All-State Welding Alloys Co., Inc., 249-55 Ferris Ave., White Plains, N. Y.

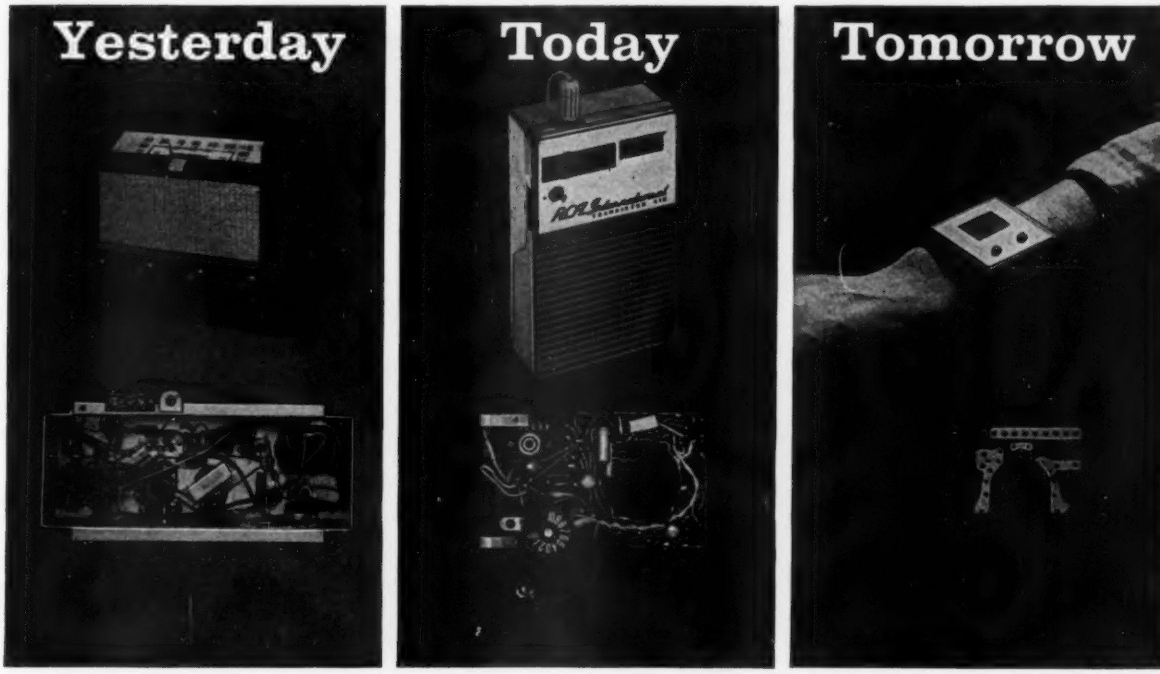
▸ A high strength welding electrode has been developed for joining low carbon, mild and low alloy structural steels. The electrode, called Eutec-Trode Super 110, is available from Eutectic Welding Alloys Corp., 40-40 172nd St., Flushing 58, N.Y.

Testing equipment

▸ A portable magnetic inspection system for detecting surface defects in iron and steel parts has been developed by Ferro Machine & Tool Corp., 5514 W. Washington St., Indianapolis 41, Ind. The machine, known as Detectascope, can be used on painted or plated surfaces to locate invisible cracks caused by grinding, welding or heat treating. The instrument sells for $795.

▸ A portable hardness tester called Sklero can be used to check metallic and nonmetallic materials on the spot. Readings are converted to Rockwell, Shore or Brinell hardness numbers by a conversion table supplied with the instrument. The unit is said to be accurate to within ± 1 Rockwell C. It was developed by Precise Products Corp., Racine, Wis.

Miniaturization of electronic components highlights need for Synthane plastic laminates



The tremendous increase in miniaturized electronic components emphasizes a need for the combined properties of Synthane laminated plastics.

Miniaturization, as you know, reduces the insulated path between terminals or conductors, placing a premium upon the insulation resistance of the laminate.

Printed Circuitry Adds to Problem

Printed circuitry, the development that made so many miniature circuits possible, also magnifies the insulation resistance problem because there is a temptation to save space by shortening the distance between conductors. And often the insulation resistance requirement is complicated by printing on both sides of the laminated circuit board.

Test for insulation resistance as conducted by Synthane Corporation.

Other Properties Influence Choice of Laminates

There are many other properties of a laminate which help to make miniaturization practical. For example, miniaturization brings the holes for terminals closer together, a result usually accompanied by a reduction in the size of holes. Punchability of the laminate, therefore, becomes an important consideration. Mechanical strength, after punching, is also worth attention.

In addition, climatic conditions greatly affect electronic equipment. Frequently, laminated plastics must retain their excellent characteristics even under the influence of heat, cold and change of humidities.

Choice of a Synthane laminate with good insulation resistance will finally rest upon the atmospheric conditions of the application, mechanical, electrical and chemical properties required, and, to a degree, upon the economics of the situation.

Synthane Laminates for Insulation Resistance

Usually high insulation resistant Synthane laminates for printed circuits are processed with selected core and surface sheets to obtain the proper balance of electrical and moisture resistance values and to provide an excellent bonding surface for the metal foil.

Synthane Grades G-10 and G-11 (glass epoxy grades) are the top plastic laminates for insulation resistance. G-11 is the stronger flexurally at elevated temperatures. Synthane Grades XXXP, XXXP-IR and P-25 have very good insulation resistance, and are easier to machine and cost less than the epoxy grades. Grade P-25 may be cold punched. Where there must be high impact strength as well as good insulation resistance Grade N-1 may be the logical choice.

Applications: Among the high insulation resistance applications of Synthane laminates are wiring cards for computers, printed circuits for television, switch rotors, automation circuits, automobile dashboard wiring.

You are urged to write directly to us or to call in a Synthane representative for help in choosing the proper grade for your application.

SYNTHANE

CORPORATION, S OAKS, PENNA.

Laminated Plastics for Industry

Sheets, Rods, Tubes, Fabricated Parts Molded-laminated, Molded-macerated

For more information, turn to Reader Service card, circle No. 423

New ideas . . . new designs with LUCITE®

ACRYLIC RESIN

MEDALLIONS of LUCITE add the selling touch to product designs. The underside of these components is molded into a decorative pattern and then metalized or painted. Beautiful three-dimensional and color effects are achieved at low cost. Parts have high structural strength. (Molded by Kent Plastics, Evansville, Indiana.)

When a light ray impinges on a Lucite and air interface at an angle greater than 42°, the entire ray is reflected. By designing the bottom interface of a medallion to take advantage of this effect, maximum sparkle and brilliance can be obtained. The prism angle used is 116°. Well over 90% of incident light is reflected to the eye at optimum angles.

To brighten up a design—to interrupt an expanse of metal with a flash of color—use medallions or decorative panels of Du Pont Lucite. It's the low-cost way to lend a touch of elegance to your products or call attention to your brand name.

Medallions and panels of Lucite are beautiful and functional. For example, a large medallion for a tractor incorporates a prismatic pattern which acts as a night reflector. Control panels for a washer-dryer combination are corrosion-proof and retain their polished look despite splashes and heat. Fastening elements, such as pins for push-in fastening nuts, can be molded right into the strong plastic shells. Lucite is a tough and impact-resistant resin.

We'll be glad to help you with the design of decorative components of Lucite. For an interesting review of design opportunities write for our brochure "A New Look at the Product Design Qualifications of a Popular Plastic, Lucite." Address: E. I. du Pont de Nemours & Co. (Inc.), Polychemicals Dept., Room L-266, Du Pont Bldg., Wilmington 98, Delaware.

In Canada: Du Pont of Canada Limited, P.O. Box 660, Montreal, Quebec

LUCITE®

ACRYLIC RESIN

DU PONT

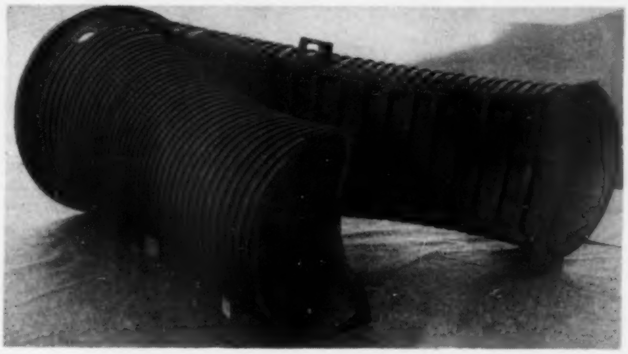
REG. U. S. PAT. OFF.

BETTER THINGS FOR BETTER LIVING . . . *THROUGH CHEMISTRY*

For more information, turn to Reader Service card, circle No. 370

Fig 1—Integrally stiffened panel is . . .

. . . stretch formed into air intake duct.



MATERIALS AT WORK

*Jet Plane—
cont'd from p 12*

Materials Used in F-104 Starfighter

1. Type 7075-T6 aluminum alloy—for high strength sheet, forgings, extrusions.
2. Type 2024 aluminum alloy—for high temperature parts.
3. Annealed titanium—for high temperature parts requiring lower density than steel.
4. Type 17-7PH steel—for corrosion resistant parts in engine room.
5. Heat treated alloy steels—for compact parts carrying heavy loads (such as landing gear) requiring tensile strengths up to 260,000 psi.
6. Type 356 aluminum alloy castings—for complicated semi-structural parts.
7. Quarter-hard 316 stainless steel—for parts requiring rigidity and resistance to high speed flutter.
8. Magnesium alloys—for sheet and castings requiring stiffness and light weight.
9. Types 420 and 431 stainless steel, and Inconel—for air ducts, tip tank ejector cylinders and boundary layer control parts.
10. Plate glass and vinyl—for windshields.
11. Acrylic—for canopies.
12. Glass-reinforced polyester—for radomes and antennas.
13. Thermosetting plastics laminates—for small nonfunctional parts.

duced directly by extruding. This method of production reduces cost and weight, and provides a smoother internal surface, as compared to conventional built-up structures.

Compression forming — According to Lockheed, this technique holds tolerances not previously possible in sheet metal parts. The sheet metal is first hydroformed to broad tolerances, then heat treated and precision formed by compression. The finished part is said to be three times more accurate than parts produced by standard forming alone—tolerances are held to ±0.010 in. across the width of the part and ±¾ of a degree on flange angles. This tech-

MATERIALS AT WORK

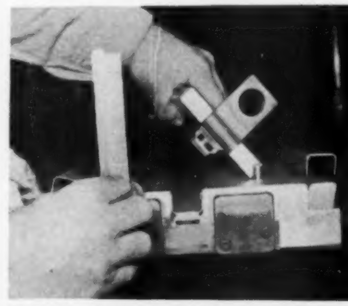


Fig 2—Compression formed rib.

nique is used to produce wing spars and ribs (see Fig 2).

No-draft forging—This technique permits very close tolerances with thin, untapered ribs; eliminates most of the machining operations previously required; and is 20% less costly than conventional machined forgings. Previously, forgings with upstanding ribs had to be made with a taper to allow the part to be withdrawn from the cavity. In most forgings this taper had to be machined off. The new technique uses higher forging pressures and precision dies. The part shown in Fig 3 was forged to fit a required contour and no machining (not even of the attaching flange which has a varying flange angle) was required. Internal radii are about one-half those used for conventional forgings.

Chem milling—Parts with localized areas of thick and thin sections were produced from one piece of stock by etch-removing unneeded material. This technique eliminates the necessity for riveting or bolting smaller

Fig 3—No-draft forged rib.

For advanced fuel...hydraulic...lube systems,

New materials prove ideal in handling temperature extremes −350° F. to +750° F.

Working with two remarkably versatile elastomers, C/R Sirvene engineers are producing flexible molded parts for many vital fuel, lubricating, hydraulic and pneumatic systems. One, Viton-A*, can be compounded to produce parts that function dependably at 600° F., and for short periods up to 750° F. The other important feature of Viton compounds is their excellent resistance to corrosive chemicals, chlorinated solvents as well as both synthetic and petroleum base fuels and lubes. At the other extreme, C/R compounded Silastic LS-53** parts are providing low temperature operation down to -80° F. They also exhibit excellent resistance to synthetic and petroleum base fluids up to 350° F., and function well in propane up to 500° F. For temperatures as low as -350° F., C/R recommends Teflon* compounds.

C/R Sirvene engineers have an intimate knowledge of these elastomers. They also have perfected special techniques in processing which still further improve the physical properties of the molded parts. If your problem involves high or low temperatures, close tolerances, and compatibility in advanced design fuel, lubricant or hydraulic systems, get in touch with us at once. We have the skill and the facilities to help you.

* DuPont registered trademark
**Dow-Corning registered trademark

CHICAGO RAWHIDE MANUFACTURING COMPANY

C/R

SIRVENE DIVISION, 1227 ELSTON AVENUE • CHICAGO 22, ILLINOIS
Offices in 55 principal cities. See your telephone book.
In Canada: Chicago Rawhide Mfg. Co. of Canada, Ltd., Brantford, Ontario
Export Sales: Geon International Corp., Great Neck, New York
C/R PRODUCTS: C/R Shaft & End Face Seals • Sirvis-Conpor mechanical leather cups, packings, boots • C/R Non-metallic gears

For more information, turn to Reader Service card, circle No. 489

MATERIALS AT WORK

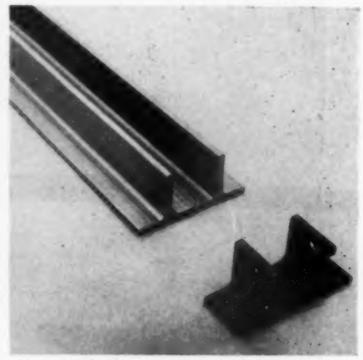


Fig 4—Extruded steel part.

parts together, or machining the required part from heavy sheet stock.

Steel extrusion—About a dozen high strength alloy steel extrusions are used in the F-104. Main advantage is the ability to produce thin sections, odd shapes and long lengths (see Fig 4). According to Lockheed, new developments now make it possible to extrude high strength alloy steels at a considerable savings in cost. Prior to these developments, complex steel shapes had to be machined from solid bars.

Phenolic Laminate Makes Best Washer

The ability of a canvas-based phenolic resin laminate to yield slightly under heavy pressures, and thus resist cracking, is the main reason given for its selection by General Cable Corp. for use as washers in an assembly used to seal off ends of insulated cable.

The washer, which is punched to provide openings for neoprene-covered conductors, seats into the end of a knurled brass fitting and serves both as a separator for the conductors and as a moisture barrier. As shown in the accompanying photo, after the fitting is screwed onto the cable, a soft sealing compound is applied to the end and the washer is seated in the fitting. The edge of the fitting is then crimped against the washer to fix it permanently in place.

Canvas-base phenolic was chosen because it combines toughness with

MATERIALS AT WORK

Taylor Fibre Co.
***Moisture barrier** for cable is made of canvas-base phenolic laminate.*

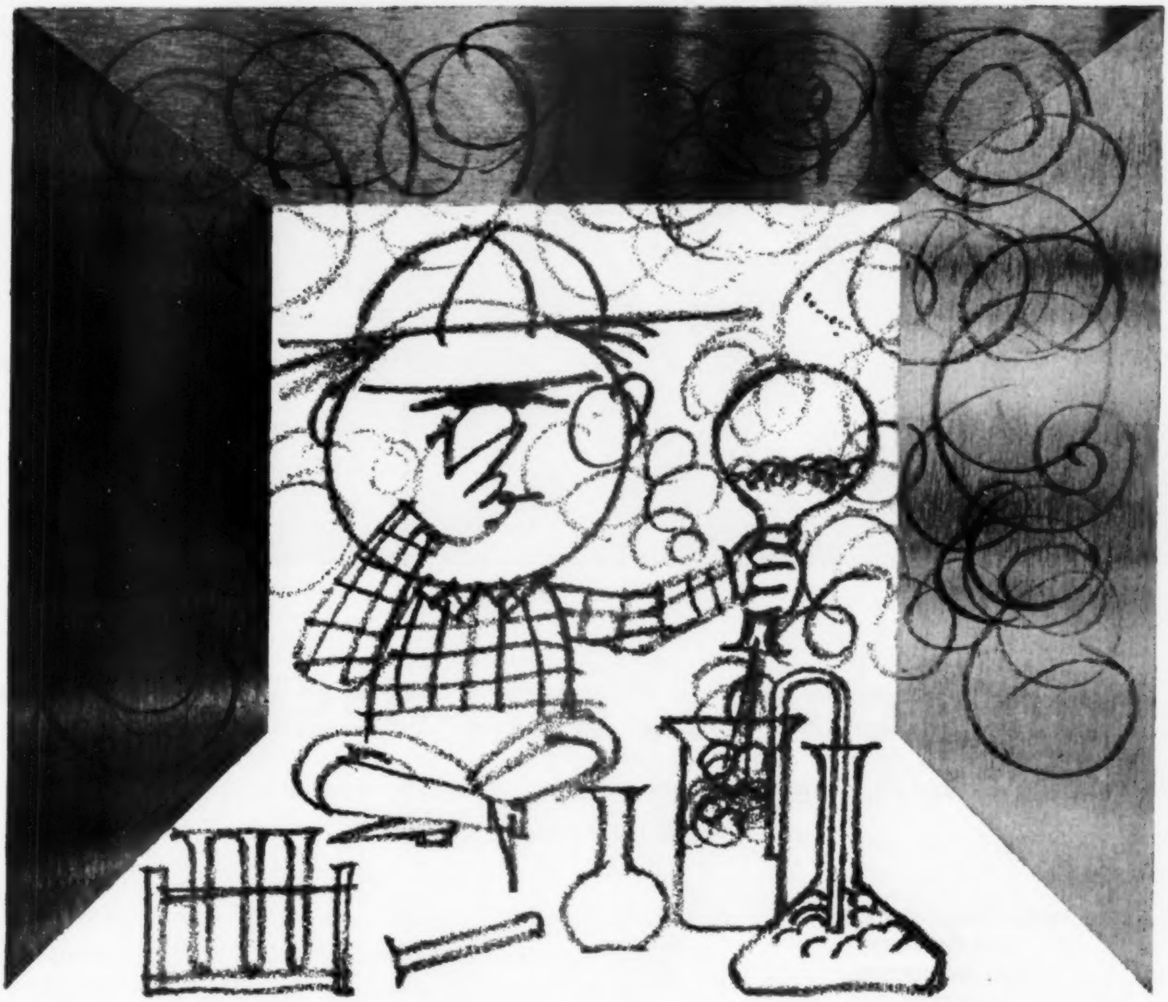
low moisture absorption, good electrical resistance and good punchability. Some washers are as small as 0.45 in. in dia and contain as many as seven lead-through holes. A paper-base phenolic was tried, but was found to lack sufficient toughness.

Large Missile Ducts Made of Stainless Alloy

A relatively new high temperature steel alloy, A-286, has been specified for the ducts used on the engines of the Atlas, Thor, Jupiter and Redstone missiles.

According to Rocketdyne, a division of North American Aviation, Inc., the ducts, which have flex joints (see accompanying photo), are used to carry liquid oxygen from the pump to the thrust chamber. Temperature changes encountered range

***Flexible ducts** must withstand temperature changes of about 600 F.*



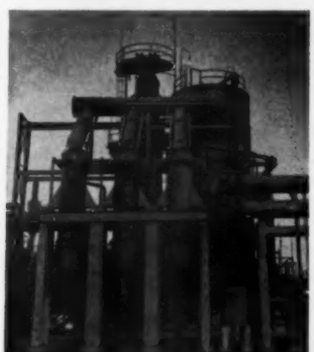
from –297 F to plus several hundred degrees fahrenheit.

According to Allegheny Ludlum Steel Corp., alloy A-286 was selected because of its 1) light weight, 2) corrosion resistance, 3) high impact strength at low temperatures, and 4) high strength-to-weight ratio at both low and elevated temperatures.

Auto Parts Are Now Vacuum Metallized

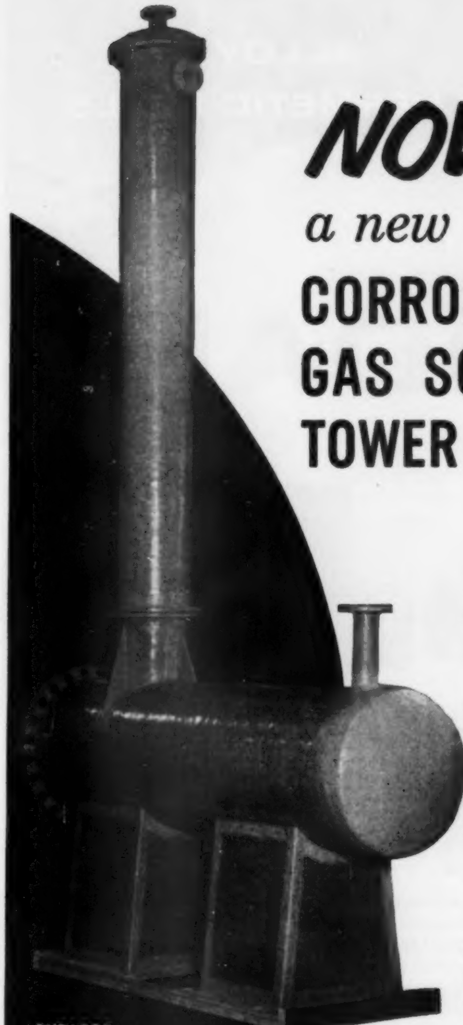
Lenses for back-up lights, heater opening covers and horn button medallions are now being vacuum metallized with aluminum by Ford Motor Co.

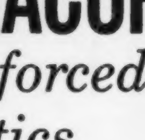
According to F. J. Stokes Corp., vacuum metallizing was previously considered suitable only for deco-



National Carbon Co., Div. of Union Carbide Corp.

Largest graphite exchanger —Shown above are what are claimed to be three of the largest impervious graphite shell and tube heat exchangers ever made. The giant heat exchangers, used in the recovery of sulfuric acid from petroleum refining acid sludge, are operated vertically and in parallel flow. Each of the exchangers contains a 45-in. dia outer steel shell which houses 685 impervious graphite tubes, each 12 ft long and 1¼ in. o.d. Total heat transfer surface area is 2685 sq ft. Approximately 50 gal per min of treated cooling water are required to handle the enormous heat load of several million Btu's per hr.





For more information, turn to Reader Service card, circle No. 386

Back-up light lenses, *worn button medallions and heater opening covers here were vacuum metallized.*

rative and novelty items, or for protected industrial components such as selenium rectifiers, precision lenses, etc. Adoption of the process by Ford, therefore, leads the way to ". . . much wider acceptance of the process for industrial finishing."

The back-up light lenses and horn button medallions are made of clear acrylic. They are first metallized on their inner surfaces and then lacquered. The heater opening covers, made of polystyrene, are first base lacquered, then baked, metallized, top lacquered and baked again.

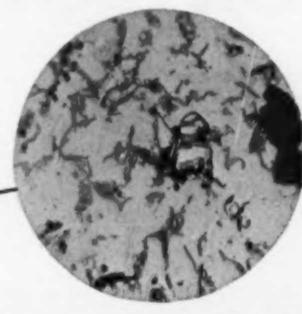
Tinplate Cuts Cost of Sanding Tool

The change from cold rolled steel to heavy gage electrolytic tin-coated steel has reduced manufacturing costs and increased life of the base

Jones & Laughlin Steel Corp.

Base of sanding tool *is now made of tinplate.*

Quality of GRAMIX® precision parts insured by metallurgical control in the laboratory *proven by performance on the job!*



Photomicrograph of a section of an inferior powder metallurgy part that has been improperly sintered. Structure is composed of cementite and ferrite.

Photomicrograph of an internally sound GRAMIX part shows the fine grain structure of tough, shock-resistant pearlite.

To assure the dependable performance of GRAMIX powder metallurgy parts in actual operation, the United States Graphite Company combines exacting laboratory tests and rigid production controls to insure the quality of every GRAMIX part. Through the use of the metallograph, for example, GRAMIX engineers can check the internal structure of a part. A comparison of the photomicrographs shown above readily shows the sound under-the-surface quality of a GRAMIX part as opposed to the poor internal composition of an improperly sintered part. In the photomicrograph at the top, notice the cementite between the ferrite grain boundaries. This cementite will tend to break up and rupture under shock. The surface of the material is decarburized and only remnants of pearlite remain. *This condition is due entirely to the lack of adequate sintering control!*

The photomicrograph of the GRAMIX part at the bottom shows a fine grain pearlite structure that's tough, strong and wear resisting. Absolute sintering control along with precise metallurgical control in the laboratory is utilized by The United States Graphite Company to positively assure quality GRAMIX parts.

Write today for these helpful engineering manuals. Engineering Bulletin No. 18 covers design and metallurgical requirements and alloy selection of GRAMIX bearings. No. 19 contains facts about GRAMIX Machine Parts and No. 21 contains general information on GRAMIX products from Powder Metallurgy. Get your copies now.

X-264-1R

THE UNITED STATES GRAPHITE COMPANY

DIVISION OF THE WICKES CORPORATION, SAGINAW 3, MICHIGAN

GRAPHITAR® CARBON-GRAPHITE • GRAMIX® POWDER METALLURGY • MEXICAN® GRAPHITE PRODUCTS • USG® BRUSHES

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For more information, turn to Reader Service card, circle No. 439

MATERIALS AT WORK

of a sanding tool as well as the dies used to make it.

The sanding tool consists of a locking handle (still made of prepainted cold rolled steel) and a sandpaper-holding base (see photo). The previous cold rolled steel base required a cadmium or nickel plate to prevent rusting. In addition, the wearing parts of the die had to be chromium-plated for protection against the steel blank.

According to Red Devil Tool Co., die life has been extended by 50% because the electrolytic tin coating acts as a lubricant during forming and blanking, thus eliminating the need for the chromium plate. In addition, the base does not have to be further protected against rust.

Carbon, Graphite Blocks Used in Acid Towers

Over 1400 individual carbon and graphite blocks went into the construction of a three-tower unit used in the production of phosphoric acid from elemental phosphorus.

Of the 1400 blocks used, about 350 are carbon (used mostly at the base) and 1050 graphite. Carbon and graphite were specified by H. K. Ferguson Co. because carbon is highly

Dow Chemical Co.

Magnesium luggage—Magnesium is now being used in a new line of lightweight men's luggage. As shown above, the luggage consists of two drawn magnesium shells and two formed tongue and groove magnesium extrusions. The complete model shown measures 26 x 19½ x 9 in. yet weighs only 9¾ lb. After forming, the magnesium shells are covered with vacuum-bonded vinyl. The extrusions are chromated and then finished with a baked enamel.

MATERIALS AT WORK

Phosphoric acid towers *consist of 1400 carbon and graphite blocks bonded with carbon cement.*

resistant to corrosive attack, and graphite offers a combination of excellent corrosion resistance, high thermal conductivity and good strength at high temperatures.

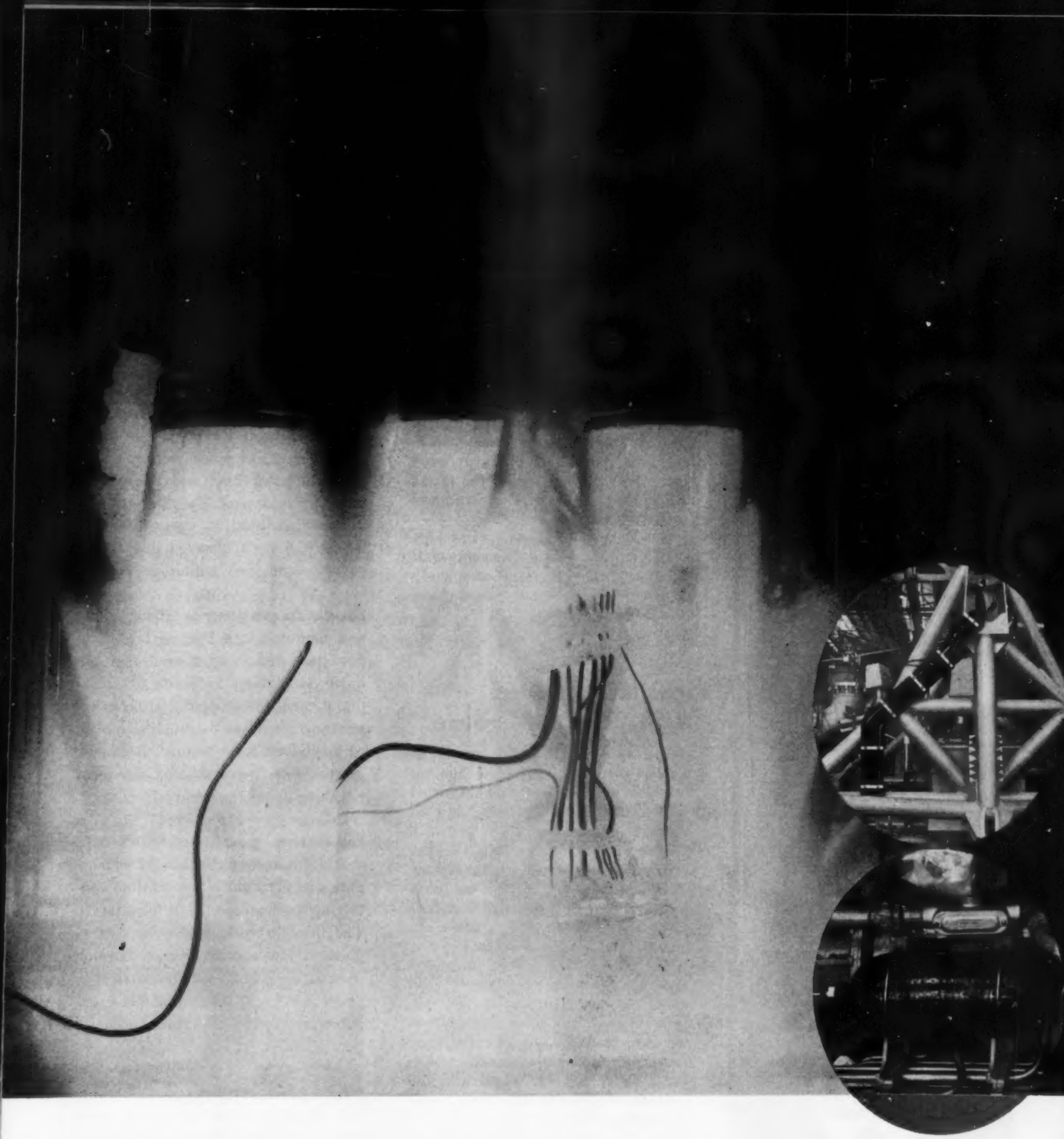
The towers are composed of built-up rings of blocks (see accompanying photo). According to Great Lakes Carbon Corp., tolerances measured on the circumference of each ring of blocks are held to within ± 0.250 in. According to the company, these tolerances are "unique" and result from "extremely skillful machining."

To simplify assembly of the towers, individual blocks were numbered and a thermosetting cement was used to seal joints between blocks.

Hastelloy, Carbon Steel Cut Process Unit Cost

By combining an expensive, but highly corrosion resistant metal with a relatively inexpensive metal, a difficult corrosion problem has been solved in the design of isomerization vessels used to process hydrochloric acid at high temperatures and pressures.

The two metals involved are Hastelloy B (a corrosion resistant nickel alloy) and carbon steel. According to Manning & Lewis Engineering Co., Hastelloy B was selected for the vessel because it provides the necessary protection against corrosion from boiling hydrochloric acid. However, the alloy is "fairly expensive and requires considerable metal-working skill to fabricate." To solve this problem, Hastelloy liners, seam-sealing strips and overlay strips,



were applied to a base of inexpensive carbon steel.

To fabricate the vessel, all carbon steel parts are first cut to size and formed. The lining material is then cut into strips 7/64 in. thick and 7 in. wide and preformed wherever possible. To make welding easier and to provide greater dissipation of heat, the strips are held tightly against the shell by means of a hydraulic jack and a hard wood form. Welding is done by the metal arc process using coated stainless steel electrodes.

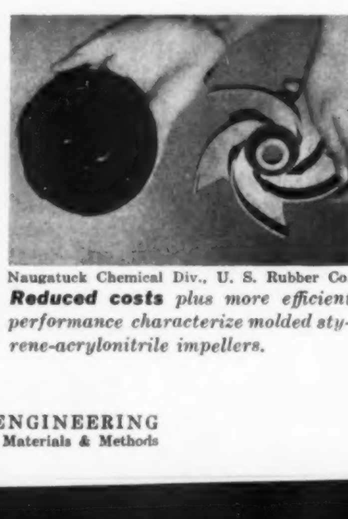
According to Manning, the cost of the 13,000-lb vessel was approximately $22,000. If made completely of Hastelloy, its cost would have been about $45,000.

Pastics Impeller Replaces Cast Bronze

The switch from cast bronze to molded styrene-acrylonitrile has resulted in reduced cost and improved performance for impellers used in water pumps.

According to Barnes Mfg. Co., the primary reason for the change was to reduce costs; the cast bronze parts were relatively expensive to fabricate and difficult to produce in quantity to close tolerances.

The new resin-rubber impellers are molded with very close tolerances. In addition, the molded styrene-acrylonitrile parts are unaffected by temperature changes, are rustproof, and have smoother surfaces which aid water passage and consequently contribute to greater operating efficiency.



Naugatuck Chemical Div., U. S. Rubber Co.

***Reduced costs** plus more efficient performance characterize molded styrene-acrylonitrile impellers.*

Bonderite's best for Aluminum, too!

Better paint adhesion, better corrosion control

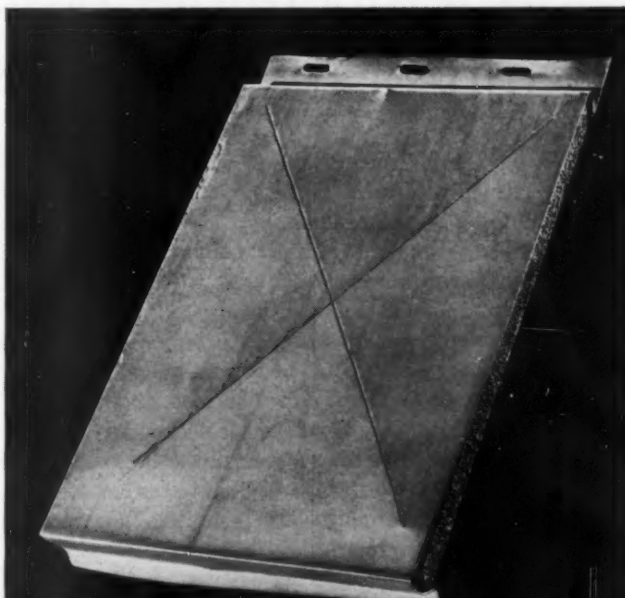
Here's the most famous name in the whole metal treatment field. Bonderite!

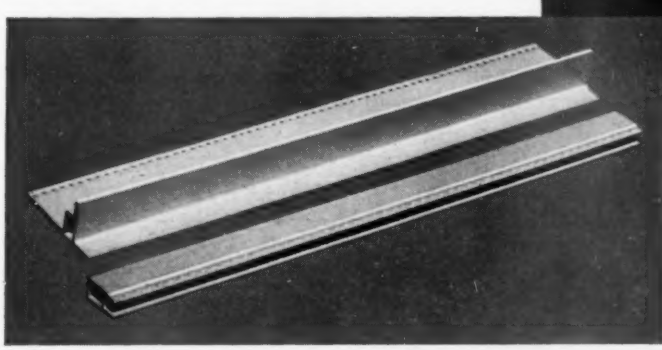
This is the product name that has meant finest finish protection and customer satisfaction to buyers of automobiles, home laundry equipment, refrigerators, metal furniture and other painted metal products for a generation.

This year, over 10 million Bonderite seals will be used on metal products to tell buyers they are getting the plus values of Bonderite protection.

As protection for aluminum, Bonderite's performance is equally spectacular. It controls corrosion, anchors paint.

Sell aluminum siding, awnings, windows, doors and panels that are protected by Bonderite. Sell with complete confidence that the product's good looks will last and last!





(Above): Regular 1-coat paint finish over section of Bonderite-treated aluminum siding. Formed after painting. Tested in salt spray 1500 hours. (Siding by Hastings Aluminum Products, Inc., Hastings, Mich.)

(Left): Aluminum window and screen frame sections Bonderized, painted in the strip, formed after painting. No breaks in finish anywhere! (Treated, painted strip furnished by Hastings Aluminum Products, Inc.)

Since 1914—leader in the field

Parker Rust Proof Company

2173 E. MILWAUKEE, DETROIT 11, MICHIGAN

BONDERITE corrosion resistant paint base	BONDERITE and BONDERLUBE aids in cold forming of metals	PARCO COMPOUND rust resistant	PARCO LUBRITE—wear resistant for friction surfaces	TROPICAL—heavy duty maintenance paints since 1883

**Bonderite, Bonderlube, Parco, Parco Lubrite—Reg. U.S. Pat. Off.*

For more information, turn to Reader Service card, circle No. 380

Mn

new specialty Wrought Iron offers better low temperature properties and better impact resistance than many steels

Mn (Manganese) Wrought Iron is a brand new specialty wrought iron offering excellent impact resistance at sub-zero temperatures. To define it: Mn Wrought Iron is a highly deoxidized, low carbon alloy wrought iron containing 1% manganese.

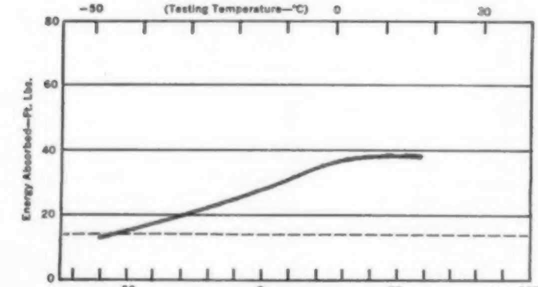
New Mn Wrought Iron is not a substitute for 4-D Wrought Iron. Mn was developed *specifically* to meet critical engineering needs for a tough, yet economical metal in low temperature services where the possibility of brittle failure poses design problems.

Independent impact testing of Charpy V-notch specimens from ½″ plate shows that Mn Wrought Iron has a mean energy absorption of 15 foot-pounds at −58°F. Mn Wrought Iron combines this boost in impact strength with the excellent corrosion resistance and mechanical advantages of 4-D Wrought Iron. Mn can be easily welded or flame cut—in field or shop—without requiring pre-heating or post-heating treatment.

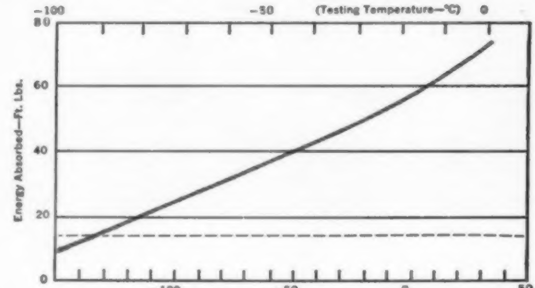
Mn Wrought Iron costs *less* initially than many of the low alloy steels recommended for low temperature service. Available in pipe, plate, and other forms, this new material is well suited for a wide variety of low temperature applications, including such services as tanks and process piping in the refrigeration and petrochemical industries.

Inquiries regarding this specialty wrought iron will receive immediate attention. Write: A. M. Byers Company, Clark Building, Pittsburgh 22, Pennsylvania.

Charpy impact values for Charpy V-notch specimens machined from conventionally-produced ½″ Mn Wrought Iron plate in as-rolled condition.



Mean energy absorption: 15 ft-lbs at −58°F, notch perpendicular.



Mean energy absorption: 15 ft-lbs at −125°F, notch parallel.

BYERS WROUGHT IRON

TUBULAR AND FLAT ROLLED PRODUCTS

For more information, turn to Reader Service card, circle No. 538

News OF INDUSTRY

ASTM Meeting To Highlight Materials Education

How to plan a program of engineering education in the materials sciences will be one of the many important problems tackled at the 62nd annual meeting of the American Society for Testing Materials, June 21-26, Chalfonte-Haddon Hall, Atlantic City, N.J.

Establishing a curriculum

This special symposium on Education in Materials will be jointly sponsored by ASTM and the American Society for Engineering Education. Specific questions to be considered are: How shall the various curricula handle materials? Shall students be given courses involving specific information on the properties of families of materials, or shall they be given courses which fall in the "materials sciences environment," involving a great deal more physics, chemistry and mathematics? What is the consensus in industry of what the graduate should know?

These questions will be discussed by a panel composed of the following leaders in industry and engineering education: Kenneth B. Woods, president of ASTM and head of the School of Civil Engineering, Purdue University; William T. Alexander, president of AIEE and dean of engineering, Northwestern University; F. L. LaQue, ASTM senior vice president and manager of the Development and Research Div., International Nickel Co.; Glenn B. Warren, president of the American Society of Mechanical Engineers and vice president of the Turbine Div., General Electric Co.; Glenn Murphy, vice president of ASEE and head of the Department of Theoretical and Applied Mechanics, Iowa State College; Professor John B. Wilbur, Massachusetts Institute of Technology; and Albert G. H. Dietz, acting head, Building Engineering and Construction, Massachusetts Institute of Technology.

". . . and then we have a hot-weather model with natural shoulders and high salt spray resistance!"

Various points of view

Other major topics to be covered by the panel are: 1) the points of view of ASTM, the educator and industry on education in materials; 2) the nature and properties of materials (ASEE report on evaluation of engineering education); 3) a discussion of the above report from the point of view of the physicist and civil engineer; and 4) a summary of a survey on projected degrees in materials engineering.

Other sessions scheduled for the 62nd annual meeting include: use of isotopes in metal analysis and testing, basic research, standardization of materials for nuclear reactors, fatigue, effect of temperature on materials, stainless steel, spectroscopic excitation sources, new polymers, and general testing.

Underwriters Restrict Plastics in Appliances

The dilemma and the confusion recently caused by Underwriters Laboratories, Inc. (UL) in the plastics and electrical appliance industries may be cleared up by now.

The trouble started with UL bulletin 484 which restricted the use of plastics in room air conditioners, refrigerators, radios and television sets to "self-extinguishing or better

News OF INDUSTRY

types." Many plastics producers and fabricators, as well as electrical appliance manufacturers, expressed concern over the ruling and requested a "meeting of clarification."

So far two meetings have been held. They were attended by representatives of the National Electrical Mfrs. Assn., the Society of the Plastics Industry, Inc., the Manufacturing Chemists Assn., Inc., the general manager of the National Board of Fire Underwriters, and the officers of UL. Unfortunately, the result was "further misunderstanding," and a third meeting has been scheduled. M/DE will publish results of this meeting as soon as they are available.

Special Courses on Engineering Materials

Here is another report on special courses on engineering materials being offered by leading universities and colleges:

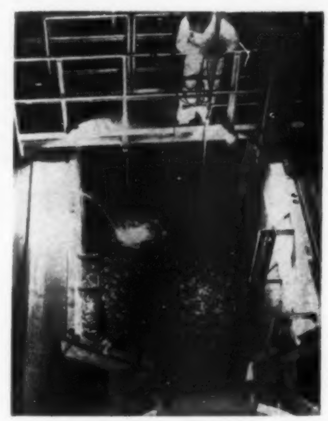
Ohio State University—Welding Engineering: covers all types of welding processes, surface preparations and testing (June 15-26); **Nondestructive Testing:** covers 1) basic principles underlying all forms of nondestructive tests and their industrial applications; 2) advantages and disadvantages of 12 individual test methods; 3) equipment, procedures and techniques of testing; and 4) interpretation of test indications in terms of material discontinuities and serviceability. In addition, the course will cover critical properties of engineering materials, effects of processing and fabrication, and the significance of service conditions and failures (Sept 14-25).

Massachusetts Institute of Technology—Bearing Technology: a summary of basic principles and new developments. To be covered are: auto-lubricated and externally pres-

USE THE 'SELECTOR'—You will find properties of most engineering materials, plus names and addresses of suppliers, in M/DE's *Materials Selector* reference issue, published last October.

News OF INDUSTRY

surized thick-film bearings, rolling-contact bearings, and boundary lubricated bearings. Also, abnormal operating conditions such as extremes of temperature, pressure and speed (June 16-26). **Mechanical and Physical Properties of Plastics:** a survey of present developments in experimental methods and techniques. Properties to be covered include: viscoelastic behavior, impact strength, molecular orientation, viscous flow, reinforcement, and stress-cracking. Test methods to be covered include: high speed stress relaxation, vibration, birefringence, x-rays, and nuclear magnetic resonance (June 22-26); **Adhesion: Theory and Practice:** survey of present status of adhesive bonding. Subjects to be covered include: solid surfaces, wetting, tackiness, setting of the adhesive, final strength of joints, stress con-



Materials testing reactor—Shown in the photo above is a view of what is said to be the first privately financed materials testing reactor built in the United States. Owned and operated by General Electric Co., the test reactor will be used chiefly for irradiation testing of fuel elements and other reactor components. According to GE, the testing facilities will also be available for research and development to organizations in the chemical, metal, petroleum, electronics, aviation, plastics and rubber industries. The reactor is capable of producing 30,000 kw of heat.

News OF INDUSTRY

centrations in joints, elastic and plastic deformation, nondestructive testing, effects of environment, strength and thickness, and essential properties of adhesives (June 29-July 3).

Previously announced

New York University—Thermoelectric Materials (June 15-19); Ductile Iron (June 29-July 3); Titanium Metallurgy (Sept 14-15).

Pennsylvania State University—Machinability (June 7-12); Plastics (June 28-July 3).

Massachusetts Institute of Technology—Corrosion (June 22-26); Materials for Parachute and Retardation Devices (July 20-31).

University of Notre Dame—Sintering and Related Phenomena (June 15-17).

Boston College—Industrial Spectrography (July 20-31).

University of Michigan—Application of Stress Analysis to Design and Metallurgy (June 22-25); Modern Approach to Machining Problems (Aug 24-28).

Special undergraduate program

Pennsylvania State University—Starting this fall, a special curriculum is being offered in engineering mechanics. Students will have the choice of two options: mechanics or materials. The mechanics option will cover the mathematical aspects and will provide specialized training for stress and vibration analysts. The materials option will provide a broad basic program by combining course sequences in advanced mechanics, metallurgy, industrial engineering, physics, chemistry, and the various engineering sciences.

Engineers

George Cory has been appointed chief engineer, Essex Conveyors, Inc.

Robert A. Heath has been named manager of engineering, Warner Electric Brake & Clutch Co.

Charles Hewitt has been made chief engineer and **William Dunn** assistant chief engineer, Vinson Mfg. Co.

John T. Lurcott has been appointed product engineer, Product Engineer-

Progress Report on

TWO NEW METHODS OF TUBULAR COMPONENTS PRODUCTION

Special metal-working techniques are being used by the Tapco Group to produce tubular members with distinct advantages for hundreds of aircraft, missile, industrial and consumer-product applications. Two of these techniques, Metal Gathering and Flotrusion*, offer important solutions to designers and engineers with the problem of tubular parts production.

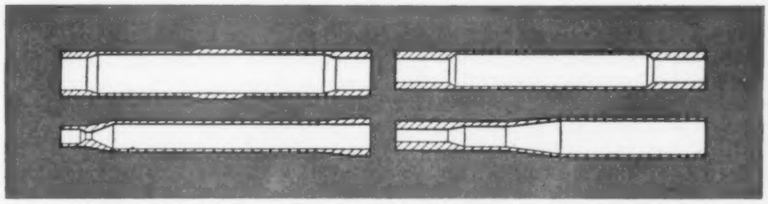


Figure 2—Flotrusion produces any desired variation in metal tubing, including those illustrated here.

METAL GATHERING

Using the Metal Gathering process, a portion of a metal tube is heated in a resistance unit, then "gathered" into a forged lump or mass at either or both ends of the tube. The heated end-mass can then be immediately extruded or forged to any desired rough configuration. After gathering or forging, any machining operation needed to finish the end is readily done right in the shops of the Tapco Group. Examples of tubing end-features produced by this process are illustrated in Figure 1.

Metal Gathering by the Tapco method offers several advantages: one-piece parts free from welds, brazing, or mechanical assembly; minimum machining for end features; no machining of tube interior to reduce wall thickness; better grain flow for greater strength and fatigue resistance; uniform heat-treatment because the whole part is formed from tubing; heavy sections are integral with tubing; no excess metal required, hence material cost is less; a rapid process for reproduction once tooling is established.

*Reg. Trademark – Used under License from Flotrusion, Inc.

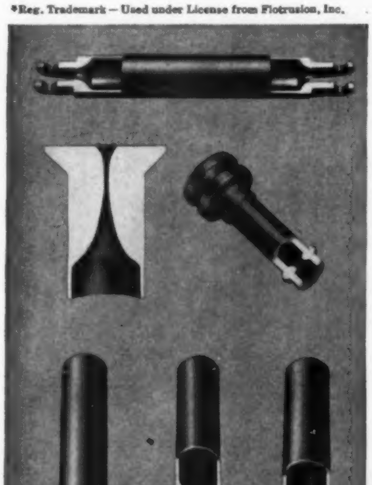


Figure 1—Typical end-features that are readily produced in tubing by the Tapco Group using the versatile, cost-saving Metal Gathering process.

The Tapco Metal Gathering process is readily applied to any metal, including steel, stainless steel, aluminum, titanium, and zirconium.

Designs are almost unlimited in size, complexity, and features. A broad range of tubing lengths, diameters, and wall thicknesses can be handled by the Metal Gathering process. Close tolerances can be supplied; grinding, polishing, or honing can be vastly reduced, and in some cases eliminated. One-piece parts replace multi-part assemblies. The process can also be used at various points along the length of the tubing.

FLOTRUSION

The Tapco Flotrusion process permits cold-drawing of tubing into various internal and external thicknesses, configurations, sizes, and shapes, shown in Figure 2. The process was developed to permit high-production rates of parts normally employing high-cost machining or polishing. Flotrusion can also be combined with the Tapco Metal Gathering process to produce an almost limitless variety of end-features, wall-thickness variations, and other features in tubing.

Tapco Flotrusion offers these advantages:

Heavy wall sections can be developed at one or both ends of cylindrical forms to provide for bearings, threads, or weldments,

Uniform wall thickness can be provided with smaller or larger diameters on the tube,

Surface finishes of excellent quality are standard, without expensive machining or polishing,

Burring and honing are not required,

Grain structure is improved, and additional heat-treatment can often be eliminated since cold-working improves tensile strength,

Tubing that has been heat-treated before Flotrusion gains added strength by cold-working,

Non-heat-treatable metals also gain strength by the cold-work effect of Flotrusion,

No excess material is required . . . Flotrusion requires only the exact volume of material that the finished part requires. Material cost is kept down.

All forgeable metals can be processed by Flotrusion . . . alloy and stainless steels, aluminum, titanium, zirconium, and others.

Tube diameters from 0.060" to 10" can be worked on present Flotrusion equipment at Tapco's completely-equipped plant. Lengths to 15 feet have been processed, but longer lengths and larger diameters are within the range of Tapco capabilities and facilities.

The configurations shown will give you ideas of how you can reduce the cost of tubular components by Metal Gathering or Flotrusion or a combination of the two. A 16-page design and data book on both processes will be sent to you on request.

TAPCO GROUP

Thompson Ramo Wooldridge Inc.

TRW

DEPT. MD-659 • CLEVELAND 17, OHIO

For more information, turn to Reader Service card, circle No. 459

News OF INDUSTRY

ing and Development Dept., Alloy Tube Div., Carpenter Steel Co.

John Liu has been appointed associate director of research and development, Clearing Div., U. S. Industries, Inc.

Russell G. Heyl, Jr. has been named chief engineer, research and development, American Metal Products Co.

Stanley Seitz is now coordinator of manufacturing engineering, American Electronics, Inc.

Cyrus C. Haynie has been named assistant to the plant manager, San Diego plant, Solar Aircraft Co.

T. C. Warner, Jr. has been appointed chief development engineer, electromechanical section, Vibration Equipment Div., MB Mfg. Co.

M. F. Filiatraut has been named production superintendent, Baker Perkins Inc.

John H. Scherer has been appointed general manager, and **Edward C. M. Homan** has been named director of research and product development, Electro-Technical Div., Sun Chemical Corp.

Allan Ray Putnam has been appointed managing director, American Society for Metals.

W. W. Durand has been named chief metallurgist, Park Works, Crucible Steel Co.

Richard H. Starrett has been appointed chief production engineer, Pfaudler Co., a division of Pfaudler Permutit Inc.

John A. Draxler has been named chief engineer, Elwell-Parker Electric Co.

Dr. Louis B. Kahn, Shell Development Co., has been elected a Fellow of the Royal Statistical Society.

Jean L. Lewis has been appointed technical director, Eli Sandman Co.

Vern H. Weatherston has been named manager of product analysis, Utah Div., Thiokol Chemical Corp.

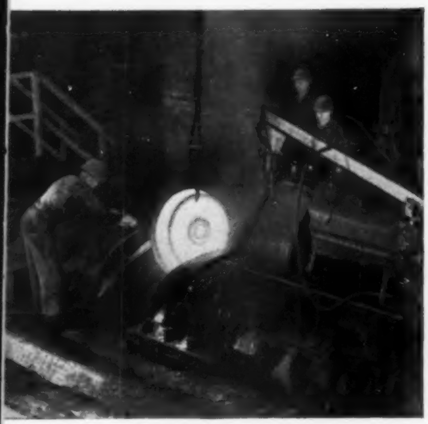
Robert A. Manogue has been appointed product manager, pumps and controls, Denison Engineering Div., American Brake Shoe Co.

George C. Stradley has been named group leader in charge of chemical engineering research, Michigan Chemical Corp.

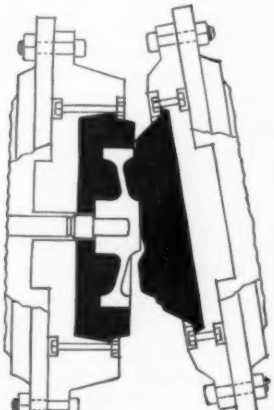
Julius P. Zeigler has been appointed to the newly created position of

Unique Mill Forges and Rolls circular products in one operation

In less than one minute, this Bethlehem mill—the only one of its kind in the country —turns out a top-quality impression-die steel forging at a cost that's hard to match.



This is Bethlehem's famed circular-products mill—the Slick Mill. Named for its designer, Edwin E. Slick, this unique machine produces impression-die circular forgings ranging from 10 in. to 46 in. OD; as-rolled weights ranging from 100 to 2,000 lb. It handles almost any grade of steel—carbon, alloy or stainless, as well as certain heat-resistant grades.

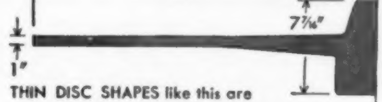


How It Works

Designed to operate in a horizontal plane, Bethlehem's Slick Mill is constructed with two *revolvable* spindles on which face plates are mounted. These face plates support the impression dies that form the steel billet into shape by a combination press and rolling action.

After the steel billet is heated and descaled, it is centered between the dies of the Slick Mill. Then a 1500-ton hydraulic ram actuates the spindle on the straight side of the mill, upset forging the billet. When this cycle is completed, a 2,000-hp motor actuates the spindle on the angle side of the mill and the rolling cycle begins. By continuing the upsetting action and rotation of the dies and work, the material flows into the recesses of the dies, resulting in the desired shape. *The entire rolling cycle takes about one minute.*

After rolling, excess material in the form of flash is sheared off; the hub, when necessary, is punched; and the forging is inspected.



THIN DISC SHAPES like this are easy to forge on the Slick Mill.

Cost-Saving Features

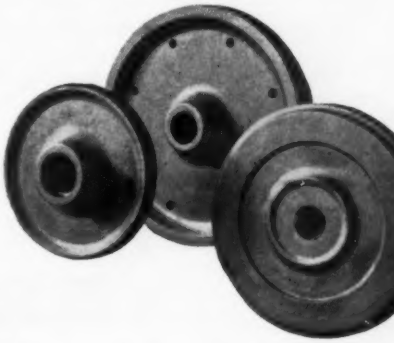
Quick operation: Only one minute is needed to convert a heated slug into a contoured forging, whether the product weighs 100 or 2,000 lb.

Quick die changes: Only 15 minutes are needed to change and set up dies. Even production runs as small as 25 or 50 pieces are economical.

Low die charges: Since contact time between die and work is very brief, and because there is no impacting, low-cost die blocks can be used. In many cases, die charges are ⅓ to ½ less than conventional impression dies.

Less steel needed: Utilizing the principle of forging design, the Slick Mill can produce lighter-weight sections without sacrificing strength.

Good physical characteristics: The process insures excellent grain flow, machinability and soundness.



Bethlehem's Slick Mill is readily adapted to jobbing or production quantities of forged circular products such as: gear blanks, fly wheels; crane track wheels; sheave wheels; brake drums; clutch discs; couplings; tire moulds; and turbine or compressor wheels. Products may be specified as-rolled or rough machined to specifications.

Your inquiry—whatever the quantity involved—will receive prompt attention. Call or write the Bethlehem sales office nearest you today.

BETHLEHEM STEEL COMPANY, BETHLEHEM, PA.

On the Pacific Coast Bethlehem products are sold by Bethlehem Pacific Coast Steel Corporation. *Export Distributor:* Bethlehem Steel Export Corporation

BETHLEHEM STEEL

BETHLEHEM STEEL

For more information, turn to Reader Service card, circle No. 464

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manager, high energy materials operations, Celanese Corp. of America.

Robert T. Steindorf has been appointed director of research and development, Chain Belt Co.

Cecil S. Allen has been named director of engineering, electrical products group, Electric Auto-Lite Co.

Erwin Rausch is now plant manager, Telectro Industries Corp.

Dr. L. J. Castriota has been named a consultant, Research & Development Div., Polytechnic Research & Development Co., Inc.

Donald E. Wolff has been named technical service manager, Plastics Div., Seiberling Rubber Co.

Robert J. Prochaska has been named advance development specialist, Chemical Materials Dept., General Electric Co.

Harold F. Schulte has been appointed chief engineer, Wheelabrator Corp.

T. R. Simkins is now director of Research and Product Development, Arvey Corp.

Robert H. Sprague is head of Horizons Inc.'s Dept. of Chemistry.

David L. Matthews has been appointed manager of manufacturing, Goodrich-Gulf Chemicals, Inc.

K. H. Carlson has been appointed technical manager of specialty steels, Latrobe Steel Co.

John Fuqua has been appointed chief plant metallurgist, Cooper Alloy Corp.

Judson W. Arnold has been named to the newly created post of director of development, Shawinigan Resins Corp.

T. Frank Saffold has been appointed manager, Specialty Transformer Dept., Westinghouse Electric Corp.

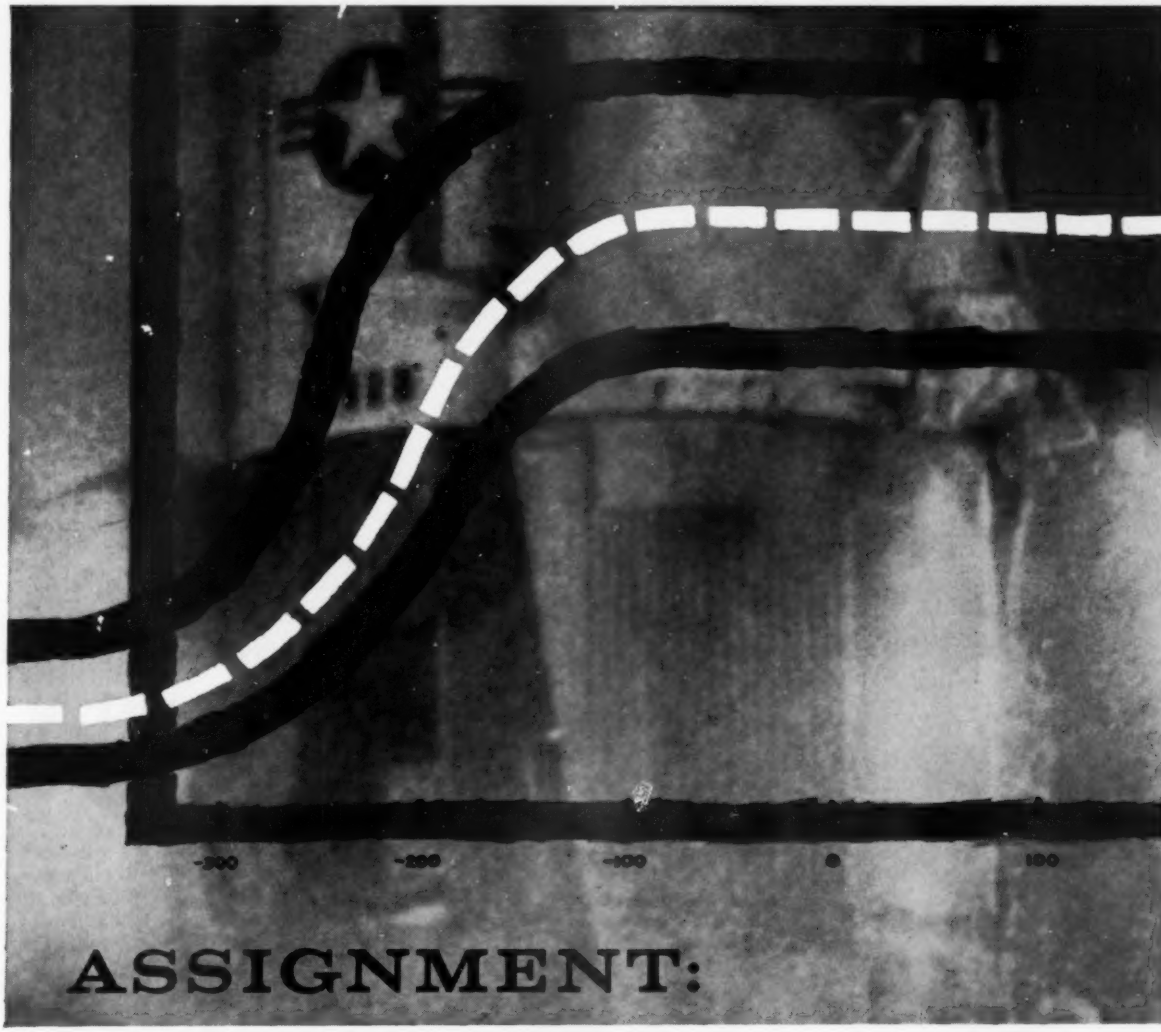
Otto J. Leone has been named engineer for steel industry applications, Bristol Co.

Philip R. Geffe is now chief filter engineer, North Hills Electric Co., Inc., Mineola, N. Y.

Howard K. Norris has been named production manager, Mechanical Goods Div., U. S. Rubber Co.

Dr. George Odian, Jerome Goodman and **David Sahud** have been named senior scientists, Radiation Applications Inc.

(News of Companies on p 218)



CRYOGENICS

How Lukens *Application Research* helps you find the right steel plate for the job

If your assignment is designing equipment for extreme low temperature service—our Application Engineering staff can help you. They research problems of every description from the design stage right through to how the equipment has performed for years after its installation.

Missile components and liquefied gas tanks would be dangerously susceptible to cracking if made from ordinary steel. Seeking economical metals for such applications, Lukens engineers began years ago to watch the performance of nickel bearing alloys in a variety of low temperature equipment. Result: a broad understanding of metal behavior at various low temperature levels.

Examples: In the storage of liquefied oxygen, a tank of *Nine Nickel steel* provided more than eight years of trouble-free performance. Suitable to minus 320°F. service the steel showed no signs of cracking when removed for inspection. In frigid chambers for testing high altitude aircraft, *2½ percent nickel steel* is standing up well under pressures as high as 7,000,000 pounds. And in arctic locomotives operating at temperatures to minus 50°F. on rugged mountain roadbeds, main structures of *Lukens "T-1" Steel* have required no maintenance whatsoever.

Lukens Application Engineers know these cases . . . plus many more. *If your assignment is cryogenics, why not let it be our assignment, too?* Contact Manager, Application Engineering, D 69 Services Building, Lukens Steel Company, Coatesville, Pa.

Helping Industry Choose Steels That Fit The Job

LUKENS

ASK FOR LUKENS NINE NICKEL STEEL BULLETIN

For more information, turn to Reader Service card, circle No. 525

News OF INDUSTRY

Companies

Vanadium-Alloys Steel Co. and **Latrobe Steel Co.** have almost simultaneously announced completion of expansion programs involving installation of new consumable electrode vacuum arc melting furnaces. Vanadium's furnace, a 24-in. unit, will be used to increase production of highly refined bearing steels, ultra high strength steels, high temperature alloys and reactive metals. Latrobe's furnace, a 20-in. unit, will be used to increase production of highly refined tool steels, bearing steels, high temperature alloys and high strength steels.

Morningstar-Paisley, Inc., has formed a new Gum and Technical Products Dept.

Crippen Laboratories, Inc., is the new name for **Crippen and Erlich Laboratories, Inc.,** a subsidiary of Foster D. Snell, Inc. Crippen Laboratories has moved to 1500 Guilford Ave., Baltimore 2, Md.

James F. Lincoln Arc Welding Foundation, Box 3035, Cleveland 17, Ohio, has announced a $50,000 Machine Design Award Program for papers describing the use and advantages of arc welding in the design and manufacture of machinery. The contest closes July 20.

Turco Products, Inc., will move into its new multi-million-dollar headquarters in Wilmington, Calif. by the end of this month.

Spencer Chemical Co. will expand polyethylene production at its Orange, Tex. plant.

Solar Testing Service is a newly-established commercial proving ground located at 4165 SW 11th Terrace, Broward County International Airport, Fort Lauderdale, Fla.

National Starch and Chemical Corp. is the new name for **National Starch Products Inc.**

Techline Div., Wheelabrator Corp., has established a new warehouse and processing laboratory at 2602 E. Foothill Blvd., Pasadena, Calif.

Hamilton Standard, a division of United Aircraft Corp., has established an advanced product planning group within its Engineering Dept.

Seymour Mfg. Co. has expanded its facilities to include the manufacture of stainless steel strip.

Electro-Mechanical Div., Neptune Meter Co., is the name of a new division formed by the merger of

News OF INDUSTRY

three wholly-owned Neptune subsidiaries—Revere Corp. of America, Electronic Signal Co., and Hot Spot Detector, Inc.

Melpar, Inc., a subsidiary of Westinghouse Air Brake Co., has constructed a new 60,000-sq ft plant near Washington, D. C.

Hesse-Eastern, a division of Flightex Fabrics, Inc., has moved to new quarters at 210 Broadway, Everett 49, Mass.

Acme Stamping and Mfg. Co. has acquired the wire forming facilities of **Townsent Co.,** New Brighton, Pa.

Fluid Regulators Inc. has completed an expansion program at its Painesville, Ohio engineering offices and experimental laboratory.

Zero Mfg. Co. has acquired 95% of the stock of **White Aircraft Corp.** of Palmer, Mass.

Holgate Brothers Co. has acquired **Nosco Plastics, Inc.,** Erie, Pa.

Battelle Memorial Institute will construct a new laboratory designed to study plutonium.

U. S. Chemical Milling Corp. has formed an **Electronics Div.** for the design and production of printed circuit boards and chemically blanked parts.

Koehring Co., Milwaukee, has acquired **Cast-Master, Inc.,** Bedford, Ohio.

Nopco Chemical Co.'s Plastics Div. will triple its North Arlington, N. J., plant facilities.

Superweld Corp., North Hollywood, Calif., has acquired all outstanding stock of **Western Carbide Corp.**

Tracerlab, Inc., has dedicated a new laboratory addition to its Reactor Monitoring Center in Richmond, Calif.

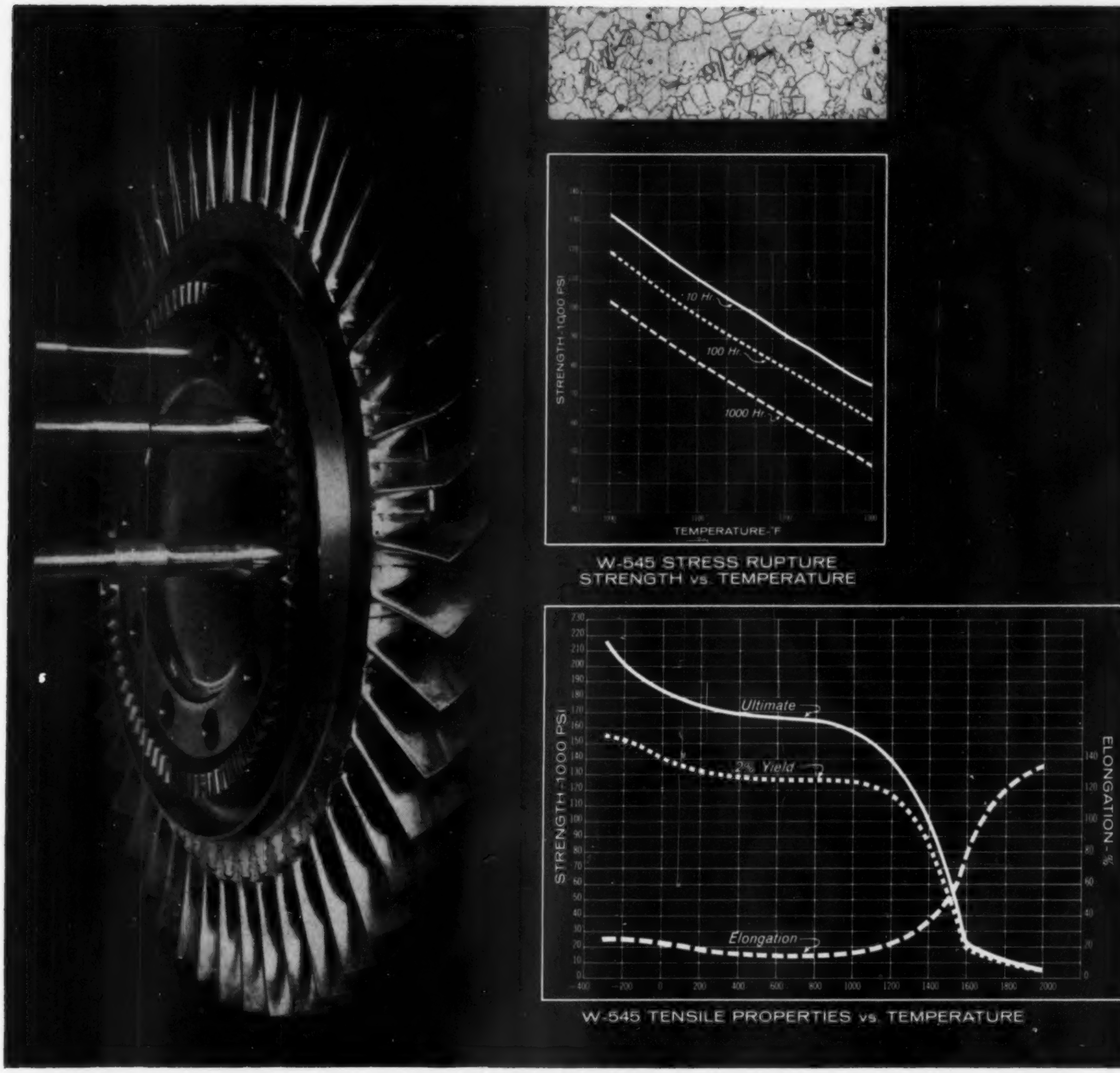
Zero-Max Co. is a newly-formed subsidiary of **Revco Inc.,** located at 1900 Lyndale Ave. S., Minneapolis 5.

International Resistance Co. has consolidated its Asheville and Boone, N. C., plants to form a North Carolina Div.

Combustion Engineering, Inc., has acquired **General Nuclear Engineering Corp.**

Techline Div., Wheelabrator Corp., has opened a new chemical laboratory at its Vicksburg, Mich., plant.

Haveg Industries, Inc.'s Pla-Tank Div. has added new plant facilities



NEW HIGH-TEMPERATURE ALLOY W-545 HAS 20% MORE STRENGTH

Twenty percent more strength at 1200°F from this turbine disc gave added dependability for a Westinghouse customer using W-545. This new high-temperature alloy will withstand higher stress levels than similar alloys at the same operating temperatures . . . or it will withstand equivalent stress characteristics at 100°F higher operating temperatures.

Critical high-temperature parts can be made from this material that have excellent strength-to-weight ratios and can be used at temperatures up to 1350°F . . . excellent characteristics at −300°F.

W-545 has proven itself superior for turbine wheels . . . compressor discs and shafts . . . combustion chambers . . . housings and skin materials. W-545 is nonmagnetic and has a low strategic alloy content, permitting ease of fabrication for fasteners . . . rings . . . spacers . . . fittings . . . brackets . . . supports and mounts.

The Westinghouse Metals Plant can furnish strip, sheet, bar, forgings and forging stock in W-545 and other wrought high-temperature alloys. Get all the information today; write: Westinghouse Electric Corporation, Materials Manufacturing Department, Blairsville, Pennsylvania.

J-05010

YOU CAN BE SURE...IF IT'S

Westinghouse

WATCH "WESTINGHOUSE LUCILLE BALL-DESI ARNAZ SHOWS" CBS TV MONDAYS

For more information, turn to Reader Service card, circle No. 508

News OF INDUSTRY

at Warren, Mass., for the manufacture of large polyester-glass chemical process equipment.

H. K. Porter Co., Inc., has formed a new division which will be known as **Mouldings Div.**

Picker X-Ray Corp.'s New York City office has been moved to 75 Varick St.

Societies

Gray Iron Founders' Society, Inc. is again holding its annual Design Contest, the purpose of which is "to give due recognition to designers, engineers and buyers of gray iron castings." Deadline for contest entries is June 30.

Welding Research Council's High Alloys Committee is currently conducting an extensive study of the intergranular corrosion of austenitic stainless steels and is searching for suitable industrial exposure sites for use in this program. Those interested in participating in the program should write to R. M. Fuller, International Nickel Co., Inc., 67 Wall St., New York 5, N. Y.

Institute of Printed Circuits has elected the following 1959 officers: president—W. J. McGinley, Methode Mfg. Corp.; vice president—R. G. Zens, Printed Electronics Corp.; and treasurer—R. L. Swiggett, Photocircuits Corp. Directors are: K. W. Clayton, Tingstol Co.; R. C. Rennie, Bureau of Engraving, Inc.; P. P. Pellegrino, Photo Color Process Corp.; and Charles Sabel, Precision Circuits, Inc.

American Foundrymen's Society has elected the following officers: president—Charles E. Nelson, Dow Chemical Co.; and vice president—Norman J. Dunbeck, International Minerals and Chemical Corp. National directors are: Norman N. Amrhein, Federal Malleable Co., Cecil N. King, Chrysler Corp.; Robert E. Mittlestead, Akron Standard Mold Co.; A. J. Moore, Canadian Bronze Co., Ltd.; William H. Oliver, American Radiator & Standard Sanitary Corp.; James N. Wessel, Puget Sound Naval Shipyard; and Donald L. Colwell, Apex Smelting Co. The following have received annual awards: *Gold Medal Awards*—Howard W. Lownie, Jr., Battelle Memorial Institute; John A. Rassenfoss, American Steel Foundries; and Fred J. Walls, Engineering Castings,

News OF INDUSTRY

Inc.; *Scientific Merit Awards* — Robert H. Mooney, General Motors Corp.; Howard H. Wilder, Vanadium Corp. of America; and Elmer C. Zirzow, Werner G. Smith, Inc.; and *Service Citation Awards* — James R. Allan, Allan Industries, Inc.; Bernard D. Claffey, Dayton Malleable Iron Co.; and Roy W. Schroeder, University of Illinois.

Meetings

AMERICAN SOCIETY OF MECHANICAL ENGINEERS, semi-annual meeting. St. Louis, Mo. June 14-18.

AMERICAN ELECTROPLATERS' SOCIETY, golden jubilee convention and international exposition. Detroit. June 15-19.

AMERICAN SOCIETY FOR TESTING MATERIALS, 62nd annual meeting. Atlantic City, N.J. June 21-26.

POWDER METALLURGY PARTS MFRS. ASSN., membership and directors meeting. Skytop Lodge, Pocono Mountains, Pa. June 22-23.

AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS, summer general meeting. Seattle. June 22-26.

DENVER RESEARCH INSTITUTE, Metallurgy Div., 8th annual conference on applications of x-ray analysis. Estes Park, Colo. Aug 12-14.

INSTITUTE OF RADIO ENGINEERS AND WESTERN ELECTRONICS MFRS. ASSN., 1959 Western electronic show and convention. San Francisco. Aug 18-21.

METALLURGICAL SOCIETY, American Institute of Mining, Metallurgical, and Petroleum Engineers, conference on properties of elemental and compound semiconductors. Boston. Aug 31-Sept 2.

SOCIETY OF THE PLASTICS INDUSTRY, INC., Midwest Section conference. French Lick, Ind. Sept 10-11.

AMERICAN CHEMICAL SOCIETY, 136th national meeting. Atlantic City, N.J. Sept 13-18.

STEEL FOUNDERS' SOCIETY OF AMERICA, 57th fall meeting. Hot Springs, Va. Sept 21-22.

PORCELAIN ENAMEL INSTITUTE, annual meeting. White Sulphur Springs, W. Va. Sept 24-26.

AMERICAN WELDING SOCIETY, fall meeting. Detroit. Sept 28-Oct 1.

TECHNICAL LITERATURE

(cont'd from p 48)

Books

Materials for Rockets and Missiles. *Robert G. Frank and William F. Zimmerman. Macmillan Co., New York. 1959. Cloth, 5 by 7 in., 144 pp. Price $4.50*

Presents engineering data on lightweight, heat resistant materials for rockets and missiles. Materials discussed include iron, nickel and cobalt-base alloys; wrought and cast alloys of aluminum and magnesium; titanium alloys; cermets; molybdenum alloys; and ceramics. Materials are compared according to their chemical composition, heat resistance, physical properties and oxidation resistance. Information is also given on fabricating processes, including high temperature brazing and ultrasonic machining.

Modern Foundry Practice: 3rd Edition. *Edited by E. D. Howard. Philosophical Library, Inc., New York. 1959. Cloth, 6 by 9 in., 464 pp. Price $15*

Well illustrated with photos and diagrams, this British book discusses the melting, casting and heat treatment of ferrous and nonferrous metals. The book's 13 chapters include information on: spheroidal graphite cast iron; pressure-cast aluminum pattern plates; shell molding; and epoxy resin patterns.

Plastic Design in Steel. *American Institute of Steel Construction, Inc., New York. 1959. Cloth, 8½ by 11 in., 94 pp. Price $4*

Subjects covered in this book are: 1) plastic theory applied to bending, 2) method of analysis, 3) effect of axial load on bending resistance, 4) bracing requirements, 5) nonsymmetrical sections, 6) haunched connections, and 7) design of continuous beams, and single and multi-span rigid frames.

Symposium on Effect of Ozone on Rubber. *ASTM STP No. 229. American Society for Testing Materials, Philadelphia. 1958. Cloth, 6 by 9 in., 135 pp. Price $3.75*

Subjects of the nine papers given in this book include: reaction of ozone with rubber; ozone resistance of elastomeric vulcanizates; prevention of ozone attack on rubber by use of waxes; quantitative measurement of ozone cracking; chemical antiozonants and factors affecting their utility; and comparison of accelerated and natural tests for ozone resistance of elastomers.

The Grinding Wheel: Revised Edition. *Kenneth B. Lewis. Grinding Wheel Institute, Cleveland, Ohio. 1959. Cloth, 6 by 9 in., 532 pp. Price $4.95*

Covers the grinding of ferrous and nonferrous metals, ceramics, glass, marble and concrete. The book, thoroughly revised and up-dated by William F. Schleicher, contains a wealth of information on grinding wheels and grinding machines.

Welding of Plastics. *J. A. Neumann and F. J. Bockhoff. Reinhold Publishing Corp., New York. 1959. Cloth, 6 by 9 in., 287 pp. Price $7.25*

Discusses hot-gas, heated-tool and friction welding of plastics. Gives information on welding plastics film, thin sheet, ducting,

TECHNICAL LITERATURE

piping, self-supporting vessels and linings. Appendices give chemical resistance, service ratings, tradenames and heat resistance of weldable plastics.

Introduction to Stress Analysis. *Charles O. Harris. Macmillan Co., New York. 1959. Cloth, 6 by 9 in., 344 pp. Price $7.50*

Discusses factors which affect strength and deformation of materials; stress and strain; stress resultants in bars; torsion; flexural stress and deformation; stresses due to transverse forces on bars; buckling phenomena; superposition of stress patterns; elementary plasticity; properties of an area; and modern notions of dry friction.

Adhesive Bonding of Reinforced Plastics. *H. A. Perry. McGraw-Hill Book Co., New York. 1959. Cloth, 6 by 9 in., 286 pp. Price $8.75*

Covers the theory, design, production and testing of adhesive-bonded reinforced plastics assemblies. Discusses mechanics of adhesive joints, laminating resins and adhesives, rheology and general properties of adhesives, adhesive bonding processes and equipment, and quality control of adhesive bonds.

Big Molecules. *Sir Harry Melville. Macmillan Co., New York. 1958. Cloth, 5 by 7 in., 180 pp. Price $3.95*

Tells what big molecules are and how they are made into adhesives, fibers, plastics and polymers. Discusses the size, chemistry and fabrication of big molecules.

Mechanical Design and Analysis. *R. R. Slaymaker. John Wiley & Sons, Inc., New York. 1959. Cloth, 6 by 9 in., 431 pp. Price $9.50*

Contains 21 case histories on problems encountered in machine design. Machine elements discussed include bearings, gears, springs, bushings, shafts and bolts. Written as a textbook for a two-semester undergraduate course in machine design.

Reports

Research RESEARCH HIGHLIGHTS OF THE NATIONAL BUREAU OF STANDARDS: ANNUAL REPORT. *National Bureau of Standards. 1958. 188 pp. Available from Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C. Price 45¢ (No. 226)*

Highlights research and development programs for fiscal 1958 at the Bureau of Standards. Describes a wide range of scientific studies, laboratory experiments, instrument developments, technical publications, and research on heat resistant coatings and metals.

Welded steel design AIDS TO EFFICIENT MACHINE DESIGN IN WELDED STEEL. *Lincoln Electric Co., 22801 St. Clair Ave., Cleveland 17, Ohio. Price $1*

The various chapters in this manual tell how to design fillet welds efficiently for strength and for horizontal shear due to bending. The manual also tells how to use steel efficiently to resist torsion and to minimize vibration. Information is given on simplified methods for redesigning cast bases and flywheels.

Fabricating beryllium STRUCTURAL EVALUATION OF BERYLLIUM PRODUCED BY SEVERAL PROCESSES. *B. B. Muvdi, Martin Co. June '58. 66 pp. Available from Office of Tech-*

For more information, turn to Reader Service card, circle No. 369

Includes processes, properties, design and applications . . .

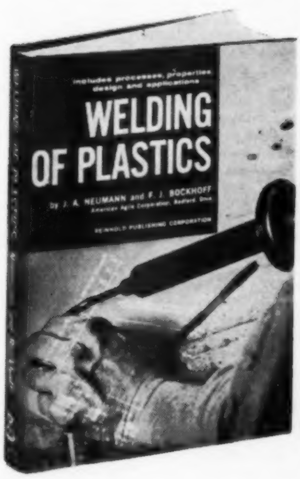
WELDING OF PLASTICS

by J. A. NEUMANN and F. J. BOCKHOFF

American Agile Corporation, Bedford, Ohio

Here is the only comprehensive treatment of all phases of this subject ranging from initial design procedures to final detailed fabrication methods. Various physical and chemical properties of individual plastics presently used for welded construction are completely covered with regard to their use in chemical and allied processing. All presently known techniques of welding are covered in detail and many step-by-step procedures with photographs are included. In addition, the book contains one of the most complete corrosion resistance tables yet published, plus a concise guide for the choice of an appropriate plastic construction material. An entire chapter is devoted solely to design considerations as they specifically affect welded construction. Testing and evaluation are also given separate treatment.

The most recent welding materials, such as linear polyethylene, polypropylene, chlorinated polyethers, and the newer fluorocarbons are covered in detail. In addition, the newest welding techniques are presented in a complete, up-to-date manner.



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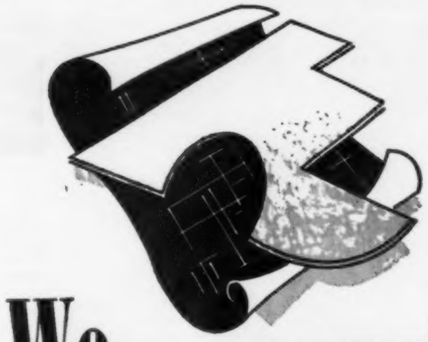

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TECHNICAL LITERATURE

nical Services, Dept. of Commerce, Washington 25, D. C. Price $2 (PB 151263)

This evaluation of five powder metallurgy methods for fabricating beryllium showed that cold compacting followed by upsetting produces plate or sheet with optimum properties. The process yielded the best combination of uniaxial and biaxial properties, gave a comparatively good surface finish, and was relatively simple and economical. Tests also indicated that the material was capable of appreciable plastic deformation before fracture.

Plastic deformation of aluminum STUDY OF PLASTIC DEFORMATION IN BINARY ALUMINUM ALLOYS BY INTERNAL-FRICTION METHODS. *E. C. Olson, R. E. Maringer, L. L. Marsh and G. K. Manning, Battelle Memorial Institute. Mar '59. 31 pp. Available from National Aeronautics and Space Administration, Washington, D. C. (No. 3-3-59W)*

Study of the damping capacity of several aluminum-copper alloys during tensile elongation. Tests show that damping depends on strain rate, temperature, alloy content and heat treatment.

Wear of metal surfaces RESEARCH AND DEVELOPMENT ON DETERMINATION OF COEFFICIENTS OF FRICTION BETWEEN DRY METALLIC SURFACES. *E. W. Gaylord and H. Shu, Carnegie Institute of Technology. Oct '57. 49 pp. Available from Office of Technical Services, Dept. of Commerce, Washington 25, D. C. Price $1.50 (PB 131943)*

Study to determine coefficients of static friction between dry metallic surfaces under high normal pressures, and coefficients of kinetic friction under high normal pressures and sliding velocities. Tested were steel rubbing on steel, titanium on steel, uranium on uranium, titanium on uranium, beryllium on uranium, and beryllium on titanium.

Heat resistant paints HEAT AND ABRASION RESISTANT PAINTS FOR ROCKET LAUNCHERS. *Rock Island Arsenal. Aug '57. 19 pp. Available from Office of Technical Services, Dept. of Commerce, Washington 25, D. C. Price 75¢ (PB 131548)*

Results of a study show ceramic coatings are superior to other types of coatings tested for resistance to rocket blast flame and sand abrasion. The test materials included ceramic, silicone, dibutyl titanate, epoxy and TFE coatings.

Cobalt-base alloys PERFORMANCE OF TWO BORON-MODIFIED S-816 ALLOYS IN A TURBOJET ENGINE OPERATED AT 1650 F. *William J. Waters, Robert A. Signorelli and James R. Johnston, Lewis Research Center. Mar '59. 30 pp. Available from National Aeronautics and Space Administration, Washington, D. C. (No. 3-3-59E)*

Stress-rupture, tensile and impact tests at 1650 F and room temperature indicate that two boron-modified cobalt-base alloys have adequate physical properties; however, buckets made of the alloys failed after relatively short periods of engine operation. All bucket failures were caused by mechanical fatigue or impact damage.

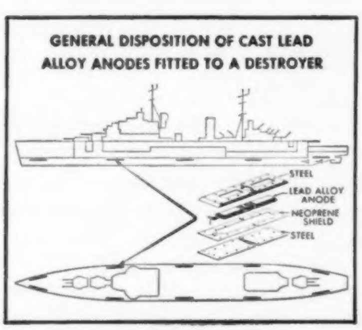
Electroforming copper parts ELECTROFORMING OF LINEAR ACCELERATOR STRUCTURES. *J. A. Pope, Stanford University. June '57. 22 pp. Available from Office of Technical Services, Dept. of Commerce, Washington 25, D. C. Price 75¢ (PB 131944)*

Describes techniques and equipment used for electroforming copper linear accelerator structures. Electroforming permits baking the structure at high temperatures for outgassing and sealing off the vacuum-tight accelerator tube. It also gives a stress-free final structure.

the LEAD *newsletter*

Atomic Generator

Qualities unique to lead help make headlines in papers throughout the world. On January 17, 1959, for instance, the front page of *The New York Times* featured the story of the then new 5-lb. atomic thermo-electric generator acclaimed as a milestone in the development of power sources for instruments carried in earth satellites. Elements in the generators are composed of lead telluride doped with other metals to provide needed characteristics. The new 5-lb. generator lasts 130 days and produces 11,500 watt hours of power. In comparison, the earlier Atlas satellite gave out only 500 watt hours of total power for only 18 days.

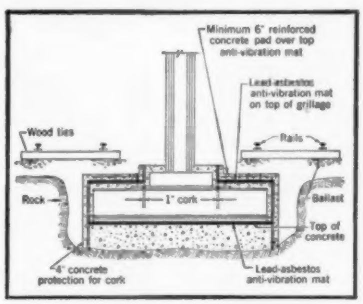


Lead Goes to Sea

Lead alloy anodes for impressed current cathodization have also appeared in the recent news. They have been approved by Lloyd's of London for the protection of ship hulls against corrosion. Also actual sea trials on a Royal Canadian Navy destroyer have shown them to be superior to anodes of graphite, steel, platinum or galvanic magnesium for both economic and technological reasons.

More Power—Longer

Less dramatic but equally important is lead's role in electrical powered industrial trucks. For this rugged use, dependable electrical power is being supplied by lead-acid batteries, of new alloys and new design. Industrial trucks powered with these new batteries are carrying loads of 1,000 lb. to over 100,000 lb., and to 30,000 lb. up grades as much as 10 per cent, at speeds comparable to other types of powered trucks and with greater economy.



Beds of Lead

Another value of lead – its vibration insulation properties – is uniquely handy for construction purposes. Lead-asbestos pads beneath 115 steel columns will cushion New York's new Union Carbide skyscraper against vibration from railroad traffic running underneath it, in and out of Grand Central Station. The operating principle of the pads is their resistance to vibration waves as they pass from one substance to another. Lead was specified for both its vibration-damping properties and its corrosion resistance which assures the durability of the pads for the life of the building. The same principle is used to insulate many other buildings, like the Waldorf Astoria Hotel and more recently to shield Montreal's Queen Elizabeth Hotel.

Let There Be Light

In some of tomorrow's buildings, you'll be able to see – literally – a value of lead. Lead's addition in small amounts to certain phosphors markedly increases their electroluminescence, the ability to emit light under electrical excitation. In paper-thin panels, these electrically excited phosphors can bathe a room in a soft, diffused light or perhaps illuminate the exterior walls of buildings.

Research and Development

Lead is currently the subject of vastly expanded research and development efforts, not only by the lead industry itself but by government, universities, research organizations and private companies. Its unique combination of properties makes it highly adaptable to modern technology as a metal, alloy or chemical compound.

Investigations are under way in the continuous extrusion of lead alloy cable sheathing, gamma ray shielding, fiber reinforced lead, sound and vibration attenuation, new and improved alloys and many other areas of product development.

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1 SILICONES

by ROBERT N. MEALS and FREDERICK M. LEWIS
Silicone Products Department, General Electric Company

1959, 304 pages, $5.95

This book's scope includes the manufacture, properties and applications of the silicones, with data on the properties of silicone resins, fluids and rubbers at high temperatures. It is aimed at design engineers, formulators and manufacturers in all industries who might have interest in silicones as chemicals, rubbers, resins, fluids, greases, adhesives and sealants. Here is a concentrated, readable summary of the technology and applications of silicones.

CONTENTS: Introduction; General Properties; Basic Chemistry of Silicones and of Combination with Other Polymers; Manufacture and Fabrication; Applications of Silicones in Various Fields; Future Prospects of the Silicones and the Broad Silicone Family of Polymers.

2 LAMINATED PLASTICS

by D. J. DUFFIN
Editorial Consultant, Continental-Diamond Fibre

1958, 264 pages, $5.75

Here is a thorough survey of the manufacturing, fabrication, and applications of high- and low-pressure laminates. It covers the various types and grades of raw materials and resins used; their physical characteristics; and includes numerous tables of mechanical, chemical, and electrical properties as related to various kinds of industrial and consumer applications. The book is profusely illustrated with photographs. The fact that the information and illustrations were compiled from a great number of sources with the cooperation of many manufacturers gives the book the broadest possible scope. The appendix features the most accurate and comprehensive list of laminated plastics manufacturers and trade names ever before offered.

and don't forget . . .

3 GUM PLASTICS
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Skeist & Schwarz Laboratories
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Director of Research and Development
Escambia Chemical Corporation
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General Mills, Inc., Minneapolis, Minn.
1958, 240 pages, $4.50

10 POLYURETHANES
by BERNARD DOMBROW
Director of Laboratories, Plastics Division
Nopco Chemical Co., North Arlington, N. J.
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11 POLYETHYLENE
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Vol. 49, Jan-June 1959

Covers feature articles, Manuals, File Facts and the most important What's New in Materials (WNIM) articles.

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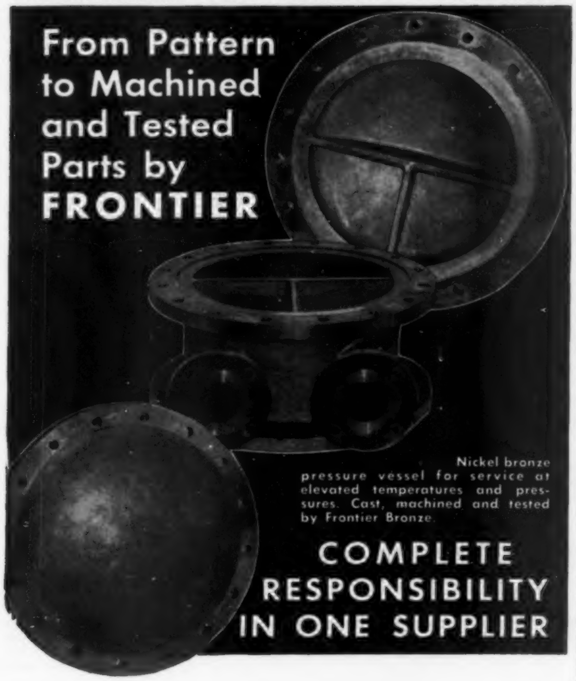
BRONZE, MONEL, ALUMINUM and COPPER CASTINGS



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Memo

TO: THE VALUE ANALYSIS COMMITTEE

SUBJECT: Alloy Castings

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B. Ferritic--straight chromium, non-hardenable. Good corrosion-resistance, can be used anywhere exposed to atmosphere or water or for scale-resisting purposes. Magnetic, machinable the same as in group A.

C. Austenitic--chromium, nickel, non-hardenable. Can be welded without subsequent heat treatment. The major percentage of castings poured by Waukesha Foundry are in this group. This group also contains the 18-8 alloys, used in dairy, chemical and food industries for contact parts.

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Who's First?

THE LAST WORD

by **H. R. Clauser**
Editor

If you have ever co-authored a technical paper or article with one or more other people, you are probably familiar with the sticky problems you can get into in composing the by-line. I have heard that in some cases more care and time is spent determining the order of mention of the authors than is spent writing the article itself.

T. E. Connolly, in a recent issue of *Perspective*, the Cornell Aeronautical Laboratory house organ, tackles this whole problem, weighing the pros and cons of some methods commonly used to designate the primary, secondary, tertiary, etc., authors of professional papers. He says that The Alphabetical Arrangement Method is perhaps the oldest on record. However, it has many shortcomings. The chief objection is that it is prejudicial to individuals in the lower half of the alphabet. To overcome this objection, methods involving games of chance, such as drawing straws or cards, or flipping or matching coins, are often used. But all of these are subject to unfair manipulation and practices.

Perhaps the most widely used system is the In-Order-of-Rank Method, in which the chief of the department always appears as senior author in the by-line. After him, all the other authors and anyone else involved (such as the office boy who mailed the manuscript) are listed in order of position. Needless to say, this method keeps controversy to a minimum.

What is T. E. Connolly's final recommendation on this problem of precedence of authorship? It is very simple: he says always publish individually and only acknowledge the help of others when not to do so would result in a punch in the nose.

One of Us Is Dead

Although technical people are very fussy about by-lines, they usually exhibit great modesty in the body of their papers. They will go to any lengths to avoid the use of "I" or "we" in their writings. All sorts of strange circumlocutions resulting from this aversion to writing in the first person can be found in the technical literature. Perhaps the classic example of all time is this footnote that appeared in an article by two authors: "Since this article was written, unfortunately one of us has died."

Operation Button Jar

Almost every household has a button jar where you can go when you need a thumbtack, a piece of string, a pair of tweezers or a stale piece of gum. Now, if things work out, there will be a button jar where universities will be able to pick up discarded, but still usable, odds and ends for their laboratories.

As a public service endeavor, two men, H. M. Reese and H. E. Miller, in conjunction with Case Institute of Technology, have undertaken this unusual project which they named "Operation Button Jar." They plan to gather discarded material and equipment from industry, reclassify it, and then distribute it to colleges. The range of odds and ends they are seeking covers everything from nuts and bolts to machine tools and testing equipment. Of course, the success of the project depends upon industry's cooperation, and they hope companies will think of Operation Button Jar before they throw away such things as manufacturing rejects, used product samples or old plant equipment.

What Is a Property?

Everyone involved with engineering materials deals with properties of materials every day. And yet we seldom take the time to think about what we really mean when we speak of a property of a material. Actually, a property is only meaningful insofar as it stands for a specific test. Thus, the only true definition of a property is a description of the test by which it is obtained.

In this issue John Campbell, our Managing Editor, has compiled a Glossary of Physical Properties and Tests (p 91) in which properties of materials are defined in this fundamental sense. It supplements his previous Glossary of Mechanical Properties and Tests (M/DE, July 1954) which has been the biggest "best seller" on our reprint list ever since it was first published.

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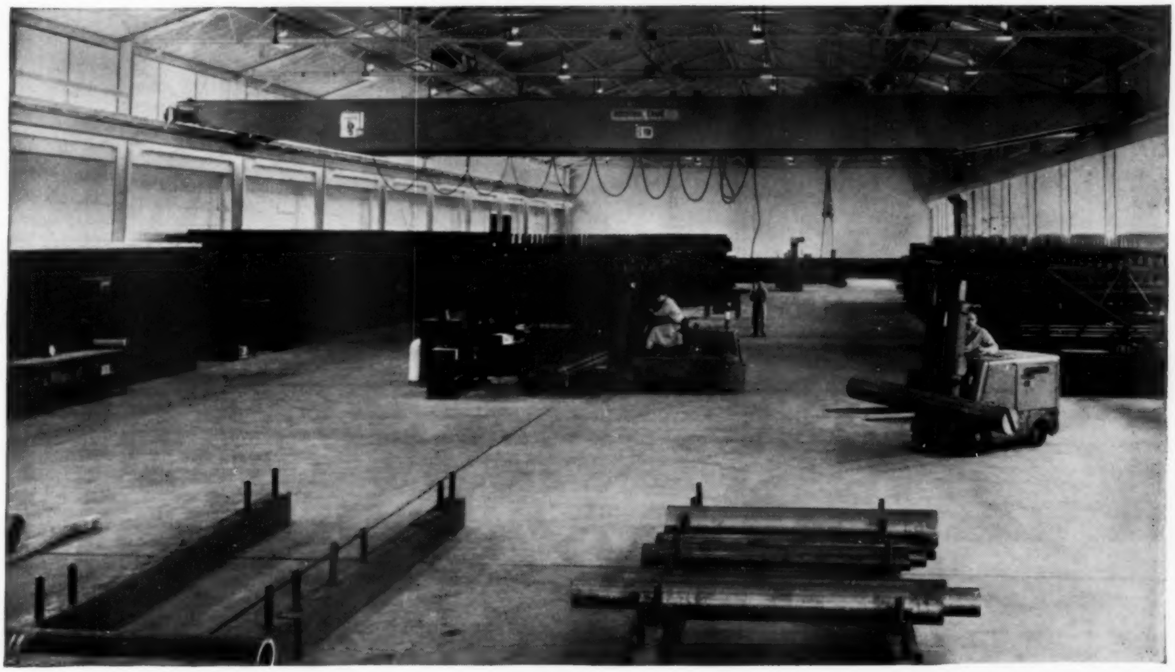

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